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ABSTRACT

The body of this paper is divided into three sections, each of which relates to the position of women in science. The authors discuss the extent of the participation of women in science careers, their motivational characteristics, the background of successful women, and the barriers presented to women in science careers. A historical perspective of the position of women in society, ranging from the middle ages to the present time, is the focus of the paper. The authors use a demographic and psychosocial approach in discussing the current status of the participation of women in science. The report reveals present patterns and future trends in education and employment for women in science. (Author/SA)

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THE EXTENT OF PARTICIPATION OF WOMEN IN THE SCIENCES

FINAL REPORT TO THE NATIONAL SCIENCE FOUNDATION

FEDERATION OF ORGANIZATIONS FOR PROFESSIONAL WOMEN

NSF GRANT GY - 11315

U.S. DEPARTMENT OF HEALTH,
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THE PARTICIPATION OF WOMEN IN THE SCIENCES

Foreword

Marie M. Cassidy

The basic purpose of this project, as originally devised, was to utilize the unique structure of the Federation of Organizations for Professional Women to ascertain the following:

Topic I. the extent of participation of women in scientific fields

Topic II. the motivational characteristics and background of women who have achieved success in scientific work

Topic III. the barriers to extensive participation by women in scientific careers

These three topics constituted the major objectives of the project.

From the informational data base available and carefully assessed at this point in time, it was expected that the coherent perceptions gained could be formulated by the Federation into some specific and cogent recommendations.

Scope

For the purposes of this study, the term "Sciences" was deemed to include a) the various disciplines of the natural sciences (biological, mathematical, physical); b) the social sciences encompassing economics, political science, psychology and sociology, c) applied scientific fields exemplified by engineering, d) cross-disciplinary fields within the sciences such as biochemistry and e) cross disciplinary fields which interface with the humanities, e.g., the history of science. This definition closely follows that of the National Science Foundation

During the tenure of the project, a reasonably comprehensive and up-to-date literature search for existing data relevant to the objectives was undertaken. Three major sources of information were immediately apparent. Firstly, there are the classical studies and reflections, some old and some very new, which are currently being catalogued by Women's Studies Centers and are fairly readily accessed through conventional library resources. A fascinating and detailed review of the role of women in science and as participants operating within varied sociocultural settings is depicted in Part I. This new evaluation of existing material spanning several centuries of activity by a marginal number of "lady scientists" is the dedicated work of a professional woman historian. It is illuminated by modern feminist perspective and the bibliographic background developed should prove extremely useful to sociologists interested in evolutionary aspects of the growing involvement of women in science.

Within the past decade, a second type of data collection has emerged. Many institutions and agencies, governmental, educational and philanthropic have been spurred by innovative legislation to direct some of their efforts to the development of information concerning the existence, education, availability and performance of women in many fields of endeavor. Many of these studies are of necessity ongoing. In addition, they are also fragmentary in that individual studies vary widely in methodological approach in terms of fields, populations, comparative female/male data, etc. Despite significant lacunae in the numerical cataloging framework for women in the sciences, knowledge relating to topic #1 is the most extensive. It is reviewed in depth in Part II of this Report by a woman physicist who is committed to that profession.

This middle section of the Report represents a current appraisal of statistical information concerning the education, employment, salary and promotional characteristics of women in the sciences. A highly important and significant aspect of present knowledge is the absence of clear correlative comparisons between female and male scientific professionsl. One critical outcome of the present study is the identification of sex-linked documentation of personpower variables as an area requiring considerable additional perusal. This particular observation was made at an early point in the investigation and prompted the solicitation of additional funds to access statistical compilation already possessed by the American Council on Education. The monies were kindly made available by the National Science Foundation and resulted in the acquisition of a computerized profile of college and university academic faculty of both sexes from ACE. The data are derived from two studies, one in 1969 and one in 1973. The study includes an analysis of many job-related factors (e.g., tenure, status, publication rate, research field) and some personal factors (e.g., marital status, children, avocation of spouse) as a function of sexual identity, doctoral status and annual income. The design of the protocol was executed by the staff of this project during the present grant. Unfortunately, the joint constraints of retrieval time for computerized data and the limited resources of a relatively short term grant precluded the analysis and assimilation of these data into the present report. We wish to emphasize both the existence of this exciting data base and our consensual opinion that there is a small but discrete mother-lode of new information awaiting mining therein by interested parties.

A third source of fresh knowledge, namely the caucus and committee reports of the professional societies, concerning the participation of women in science is directly related to the new surge of feminist thought in the '60's and '70's. Historically, scientific societies in the major disciplines were developed to facilitate scientific communication and validation of new scientific concepts. In effect, the establishment of a new sub- or cross-disciplinary field is often heralded by the parturition of a new professional society complete with a clearly identifiable autonomous journal. A recent doctoral work has attempted to explore the relationships between the characteristics of scientists and their views of the way such societies function.[1] The results obtained indicated that a majority of the biomedical scientists interviewed considered the annual meeting a unique function of their professional society because it "brought together scientists on a national basis, providing a means for interpresonal communication, socialization and professionalization." The emphasis is ours and is offered as a prelude to the following description of the arousal of feminist philosophy within precisely these same societal structures during the past decade. Other interesting facets of this study were that those questioned considered two other major points to be truly relevant to their own interest in their professional society. One, they did not publish primarily in their societies' journals and did not join societies to receive journals or informational resources; two, they mainly felt that societies should devote foremost attention to public education. By this was implied any attempts to develop a public appreciation of science, including information dissemination and policy advisement.

The organization of women within these structures has had a common pattern. In most cases, the coming together of a few vita, dynamic women scientists was the catalyst for organizational growth. Because of the usual proportionately small female representation, particularly in fields such as science, medicine and engineering, the woman scientists involved were disparate in age, background and experience. In many situations, a single incident precipitated a covert meeting which later became a caucus group. They then successfully ushered the exclusively male executive board members through a series of resolutions designed to encourage women to enter their particular profession and to create a new and change climate of psychosocial support for women neophytes in the profession. The creation of professional grievance procedures, institutional support for open advertisement of jobs, professional backing for the Equal Rights Amendment, et., were typical foci of interest. These first small groups of women were geographically dispersed and most often unfunded. They became coherent operations, and gradually assumed the status of fully-fledged orthodox committees of the societies. As such, they had several of their requests complied with and were nominated and elected to the councils of power in numbers disproportionate to their numerical representation within the professional societies. They were, very often, a lever for meaningful social change in that once any issues of justice, ethics and philosophy were exposed by dehiscence during the parliamentary debating procedures peculiar to the public business meetings of such societies, then all such issues became subject to exploration and discussion. It is interesting that while male scientists do not totally reject social concerns, it has been demonstrated that women scientists tend to outdistance their male peers on measures of social interest.[2] Clearly, it is still possible and likely that ambitious, achievement-oriented professionals of both sexes will restrict the scope of their intellectual potential to the 'hard' cocoon of objective scientific investigation. Just as clearly, the cultural effects of cumulative prejudice, non-acceptance and stereotypical classification will continue to be the concern of humane, mature practitioners of science as an adjunct to their mission-oriented careers.

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[1] Levitan, Karen Brownstein, Functions of Scientific Societies: Views of Biomedical Scientists, Ph.D. Thesis, University of Maryland, 1976.

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[2] David, Deborah. "Male Values and Female Professionals: Women in Science and Engineering." Research Issues in the Employment of Women; proceedings of a workshop sponsored by the National Academy of Sciences, September 1974, p. 135.

A relatively late consequence of women thus sharing their perceptions and seeking career advice from each other was therefore the stimulus for our third source of information. In an intense desire to know as much as possible about each other most of these caucuses and committees have, with little or no fiscal support, developed extensive questionnaires and documentation of the female membership of their scientific groups. Several of them may lack the input of an experienced sociologist in the construction of the data form but this deficiency is probably more than offset by the insights offered by those who are actually representative of the group being surveyed. Several members of affiliate groups of the Federation of Organizations for Professional Women have already published these data [3,4,5] and this project has in fact stimulated many other studies of a similar nature.[6] This type of study has usually included attempts

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[3] Kashket, E.R., Robbins, M.L., Leive, L. and Huang, A., "Status of Women Microbiologists," Science , Vol. 183, February 8, 1976, p. 488-496.

[4] McAfee, Naomi J., "Women in Engineering," New Engineer, March 1973.

[5] Henderson, Bonnie C., "Women in Geoscience," Geotimes, September 1972, p. 24-25.

[6] Cassidy, M.M., McCrea, M.B., Guttman, R., and Hare, D. Results of a questionnaire survey of the women members of the Biophysical Society: presented to the Biophysical Society Council Meeting, Seattle, February 1976.

to probe the attitudinal and motivational reflections of functioning women scientists and has been designed to evoke their individual consideration of existing barriers to enhanced participation by women in their own discipline.

These collective informal caucus and committee reports developed by volunteer labor are utilized in both Parts II and III. The concepts derived from the dissemination of this material is, however, an intrinsic component of the entire project and may also be proferred as one raison d'etre for the genesis of the Federation per se. Appendix I contains the first concise collation of such a data base and allows identification of existing gaps in current knowledge. One aspect of the somewhat ad hoc organization of these professional caucuses and committees and one which may become crucial in the next decade is that they are beginning to provide for sponsor-protegee relationships normally considered essential for admission to the upper echelons of the occupational elite. Epstein[7] has pointed out the difficulties encountered by women in forming these relationships within their own institutions. A network of successful women scientists supportive to younger women which is national rather than institutional may be a necessary career substitute. The problems faced by women students vis a vis male mentors in overcoming the barrier offered by the "invisible college" syndrome is being addressed mainly in terms of enhanced participation of women in science. The converse sociocultural difficulty of the male student/woman faculty protegee sponsor relationship is thus far imperceptible but must of necessity emerge if progress towards equality is to be made.

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[7] As cited in "Some Social Factors in Career Choice." Robin, Ellen Page, Research Issues in the Employment of Women; Proceedings of a workshop sponsored by the National Academy of Sciences, September 1976, p. 37.

Discussion of psychosocial factors affecting the entry and participation of women in science leads us to consideration of topics II and III of the original objectives. From the literature examined so far it is possible to conclude that significant involvement of women in science would require that in addition to "open enrollment" for females there occur dramatic alterations in the structure of science, psychological attributes of women, cultural norms and supportive social arrangements. Fields such as science and engineering, as presently constructed, are excellent vehicles for the reinforcement of masculine value systems. Women who succeed have, to a greater or lesser degree, to perform in accordance with the criteria of that system.[8] The limited numbers of women in the sciences result from early and cumulative discouragement of young females by parents and educators, alike. Whether one looks at toys or teachers, principals or parents, the lack of role-models or the pervasiveness of traditional role-playing, it does not seem to be an accident that there are so few women scientists. It can be ascertained from Section I that the exceptionally gifted and dedicated female has never been totally absent from the scientific scene. The personal and societal cost of pursuing such an avocation with a double X genetic endowment cannot be estimated historically. The potential Nobel Laureate of either sex, however, is a tiny minority within a vast majority of competent scientists functioning today. Nonetheless, women who attempt to join the rank and file membership of performing scientists are frequently subject to comparison with a mythical concept of superiority or excellence. A woman is often perceived as having the right to succeed but not the right to fail. A 1971 study of all chairmen of graduate departments revealed this attitude very clearly. The results of this survey[9] showed that was a definite tendency to favor an average male over an average female but to recognize a superior woman.

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[8] David, Deborah. "Male Values and Female Professionals: Women in Science and Engineering." Research Issues in the Employment of Women; proceedings of a workshop sponsored by the National Academy of Science, September 1974, p. 131.

A wide range of unsolicited comments concerning the female resumes used in this study were offered covering personality, childcare, partner's job opportunities, etc. Nonesuch were offered with respect to male applicants. It appears that, among other attributes, adequate to good interpresonal skills are a necessary prerequisite for success as a female scientist but not as a male scientist. The point was made rather succinctly in a comment by an Assistnat Commissioner of Education of New York in the New York Times in 1975 when he remarked that equality is not achieved when a female Einstein gains tenure: it is when a female schlemiel moves along in rank as fast as a male schlemiel.

Part III deals with an analysis of those factors which seem to be crucial for the future participation of women in science. This portion of the report focusses on trend projections issued by the National Science Foundation in the areas of a) education trends, b) employment trends and c) psychological and sociological factors which contribute to the status of women in science. This last part is based both on experimental work in the field and analytical studies trying to interpret various changing phenomena. Most appropriately, from among the triumulierate staff of the project, it has been written by a woman doctoral student in psychology with the insight available to someone on the 'supply' side of the professional training equation.

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[9] As cited in the Federation of American Scientists Bulletin, Vol. I, No.2, October 1973, p. 8.

By and large, the observations which may be drawn from these projections and others, taken in conjunction with the material developed in Parts I and III, are as follows:

a) Women's share of professional and technical occupations in 1974 was actually lower than it was in 1940. The discrepancies which exist are even greater when tangible rewards, e.g., salary, rank and intangible rewards, e.g., support, affirmation and approval are examined.

b) There is a general expectation that in the '70's and '80's the proportions of women participating in graduate level programs in science will be greatly enhanced.

c) One of the reactions in academia to the affirmative action programs designed to enhance the education and employment of women has been the rebuttal that the pool of qualified women is not equal to the demand required by recent legislation. Proponents of the point of view that the pool size of qualified women available is too small include Professor Lester,[10] a former Dean of Faculty at Princeton University. In a monograph derived from the Carnegie Commission study on twenty of the country's leading universities, he advances the idea that the hiring of women and minorities has impaired the quality of these schools by lowering standards and undermining faculty quality. He concludes that the "reasonable goals and timetables" criteria inherent in affirmative action have been a failure and instead suggests an alternative commitment

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[10] Lester, Richard A. Anti-Bias Regulations of Universities: Faculty Problems and Their Solutions, McGraw-Hill, 1974.

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to increasing the supply side of the equation. He believes this solution could be achieved by improving the quantity and quality of available women by greater emphasis on graduate training. Since Lester has produced no documentation for his conclusions and indeed we have been unable in this study to discover the existence of any solid data at all concerning the impact of affirmative action, the 'phenomenon' of lowered quality detected by him is essentially a porjection of what might occur should affirmative action agenda currently being written be actually executed. Nonetheless, the opinions expressed by this author are critical to an evaluation of the future participation of women in science for the following reason: they were formulated following discussions with faculty and administrators of our most elite educational institutions. These people could be said to hold positions of inestimable power with respect to the future advancement of women within the sciences and hence their reflections must be addressed if progress is to be made. Science is a highly prestigious occupation and fears that a greater recruitment and elevation of women in science may diminish that prestige may not be unfounded. However, we have not uncovered any evidence in this project to indicate that the scientific professions are being more pressed in terms of providing equality of the sexes than any of the other professions. In fact, the evidence availabe would support the contrary view.

d) In several of the sociological studies on women who are currently functioning as scientists, and in the attitudinal comments to be found in the caucus and committee reports (Appendix) and in numerous conversations of the project staff with senior women scientists there is a common thread of deeply held subjective belief. And it is that, to have attained the necessary educational skills and to have performed successfully in the absence of general societal approval and supportive community services may mean that such women are in effect more capable than their average male colleague. A participant in a recent confenence on graduate and professional education of women accurately described the inducements offered to women in undertaking graduate education: "working hard, proving themselves super competent, facing disapprobation and hostility because they are trying to do something women should be doing, seeing very few or no female faces in positions of respect, prestige or academic leadership."[11] At this nexus in time, significant numbers of the women in science juggle scientific performance, housekeeping and family duties, in addition to teaching and providing nurturant roles for students. The complexities of these multiple tasks when set alongside the traditional concept of the totally involved, dedicated and catered for male scientist have not been adequately explored although a recent National Academy of Sciences Symposium has posed some fascinating questions.[12]

e) According to one esteemed economist, at least the latter half of the '70's and '80's decade will see the production of one-third to one-half too many Ph.D.'s for the types of employment we have known in the past. The cost of this surfeit of highly educated personnel is rising underemployment but "the human cost in unfulfilled expectations and discouragement may be even more important."[13]

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[11] Tidball, M. Elizabeth. Women Role Models in Higher Education; proceedings of a conference entitled "Graduate and Professional Education of Women" sponsored by the American Association of University Women in cooperation with the Association of American Colleges and the Cooperative College Registry, p. 57.

[12] Research Issues in the Employment of Women; proceedings of a workshop sponsored by the National Academy of Sciences, September 1976.

Some provocative issues emerge from this tripartite approach to the participation of women in scinece when viewed from the past, in the present and the future. There has and continues to operate what might be called an exclusionary principle with respect to the involvement of women in the scientific professions and one which has been noted in other fields of endeavor. Namely, with very few exceptions in science, regardless of the occupational status encountered the proportion of qualified women involved is extremely low. In addition, the more highly prized the specific professional status inspected, the smaller the number of females represented, leading to the phenomenon recognized be feminists as 'clustering'. An empirical and recurrent question addressed to those interested in feminist issues is whether this clustering of working women at the junior and lower-paying position level is a consequence of conscious or unconscious 'voluntary' choices made by women or whether in fact it is due to exclusionary discrimination, overt or covert exerted by powerful practitioners and institutions in particular fields. An answer of sorts to this often rhetorical question may be forthcoming within the next decade.

We have seen that academic porfessional and governmental institutions are generally committed to the concept of increasing the availability of graduate education in science for women. Both feminist and popular literature encourage the young woman of today to pursue her talents to the fullest, and to consider exercising them before and after and possibly even during child-bearing and rearing. On the other hand, the depressing lack of evidence that sexist hiring and promotional practices have altered, coupled with the economic predictions of an oversupplied and heavily overtenured professional market, lead to at least one distressing conclusion. The unique perspective afforded by this project leads us to overstate perhaps, a possible dilemma of the '80's in what might be termed a "feminist Club of Rome" statement. We believe that insufficient attention is currently being given to the likelihood that the participation of women in science in the next decade may reveal significant numbers of very angry young women. Elevated educational attainment and stimulated ambitions together with the relative absence of discrimination at the pre-doctoral level will leave women unprepared for the realities of the marketplace and the traditional operating structure of the scientific disciplines.

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[13] Carlter, Allan M. "Scientific Manpower for 1970-1985." Science, April 9, 1971. Vol. 172, p. 138

In the face of even moderate restricitons on job availability and mobility, history would not lead us to be sanguine about the statistical chance that even a well qualified female scientist would be hired or tenured as frequently as an equally well qualified male scientist.

We await the future with interest . . . . and trepidation for our sisters and our daughters.

Marie Mullaney Cassidy
Chair, Advisory Council to the project
"The Participation of Women in Science"

Federation of Organizations for Professional Women

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THE ROLE OF WOMEN
IN
SCIENCE AND SOCIETY

A Historical Perspective

Jane Aufenkamp

SECTION 1

Historical Introduction

The position of women has been called the test point by which the civilization of a country or of an agency may be judged, and although this is in many respects true, the test remains one which is extraordinarily difficult to apply, because of the difficulty of determining what it is that constitutes the position of women. Their position in theory and in law is one thing, their practical position in everyday life another. These react upon one another, but they never entirely coincide, and the true position of women at any particular moment is an insidious blend of both.

Eileen Power
The Legacy of the Middle Ages

Only be making . . . an adjustment to the realities of the pattern created by our previous history can the number of women at all levels be increased substantially . . . .

Vera Kistiakowsky
Women in Engineering, Medicine and Science

Our best women -- those in whom society has invested most heavily -- underperform, underachieve, and underproduce. We waste them and they waste themselves.

Cynthia Fuchs Epstein
Woman's Place

Historical Introduction

At present, especially in the industrialized world, science occupies an overwhelming place of predominance. Both pure and applied sciences shape our lives. At the same time, our society seems to be in an era of transition and uncertainty where values and attitudes about everything are being re-examined. As a result, the sciences, still pre-eminent, face an ambiguous future.

In addition, there is a demand that everyone be given equality of opportunity in all areas. While claims for egalitarian societies have been made before, the distinctiveness of the present movement, in part, stems from the fact that so many groups within our society are making this demand at once. Here in the United States, this has led to the insistence that minorities and women be allowed to participate fully in the professions and in the sciences.

The purpose of this portion of our study is to examine the status of women in the sciences in the past and to try to point out factors that played a decisive role in the present role of women in the sciences. It is our contention that, at present, women are accorded a marginal and somewhat ambiguous status in the sciences and engineering, even in those fields in which they are most heavily represented. This contention is based on the work we have done to document the opening quotation of Eileen Power's " . . .the status of women is the test point of an era or a civilation."[1]

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[1] Power, Eileen, "The Position of Women," The Legacy of the Middle Ages, ed. C.G. Crump and E.F. Jacob, Oxford, England, 1926, p. 401-433.

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Other people might choose other groups depending upon their view of what is important within society. However, we submit that when roughly half the population of a society is accorded a marginal and ambiguous status and when their roles and opportunities are controlled by others, then the fabric of that society is weak and the quality of life within it is lessened. Briefly stated, the thesis of the historical portion of this investigation is that the "marginal and ambiguous status" accorded women in the sciences and engineering at present originated as a result of the interplay among the following three historical factors: the development of science as an institution within society as we know it today; the social and legal positions women occupied in certain key periods in the past and the influence of these factors; and the extent to which women have participated in the sciences in the past and under what conditions they functioned and how this past participation has played a role in the present status of women in these fields.

Throughout the historical section we will present documentation for these contentions and show how values and attitudes of the past have played a part in defining the role of the woman scientist today. As the quotation of Vera Kistiakowsky, also on the opening page, suggests it is not enough to examine our present condition [though this is our major goal,][2] but we must also look to the past to see how we arrived at our present position. It would be faulty both sociologically and scientifically to ignore this heritage and say with Henry Ford, "History is bunk."

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[2] Kistiakowsky, Women in Engineering, Medicine and Science, Washington,D.C.: National Academy of Sciences, National Research Council, Rev. Ed., September 1973, p. 59.

Originally, this section of our survey was intended to serve as a kind of framework in which the analysis of the data and literature related to the current extent of the participation of women in the sciences and engineering could be presented. The main intention was to describe some of the efforts to alter some of the literature and events that led to these efforts.

The main sources for the framework were to be the commission and committee reports on the status of women within the professional societies of the various scientific fields. Almost all these reports had two things in common -- a description of what had led to the formation of these committees and certain works on the sociological and psychological conditions which affected women in all the professions had been used as a guide to crystalize thinking about how to evaluate "the status of women scientists." Also of importance was the fact that these reports tended to encourage other women scientists to form committees and evaluate the conditions under which they worked.

However, in the process of collecting and reading both the reports and other literature on the status of women in science, enough material of a historical nature, though not primary sources, was collected and it justified a different approach.

That is how this part of our investigation started and it should be evaluated with this background in mind. It is in part of re-reading of some of the "record" and some of the interpretations of the "record" that seem to us to be pertinent and to offer some insight into our main area of investigation and as part of the steps toward an understanding of the role of women throughout the past in sciences.

The overall methodology of our report has been described in the main Introduction. However, the historical section, while fitting into the general framework, has a particular methodology. Original research, as defined by historians, has not been done. Nor are the commission and committee reports the main focus of this section. Instead they are integrated into the section on the present status and participation of women in the sciences.

Definitions of science, scientist, woman scientist and professional presented in the main Introduction apply throughout this section with two differences. The definitions of these terms held in the historical periods examined are also set forth. Also throughout the historical section science is treated as an institution rather than a set of activities. The reason for this is that is science as an institution in which women function. Therefore, rather than dwelling on great accomplishments or scientific "revolutions," science is presented in this section as a multi-faceted, more or less organized set of activities within society.

As is immediately apparent in reading this section we violated the sacred historical precept to begin at the beginning and go on until you come to the end. We decided, for purposes of this report, to "stand history on its head" and begin at the period in the United States just before the present.

However, assigning precise beginning and end dates for the 'period in the United States just before the present' was not quite so easily accomplished. The main difficulty is that the events of the second half of the nineteenth century through tht twentieth century up to around 1970 have a close dependence upon one another especially when examining developments in the sciences and the status of women.

As Margaret Rossiter points out in her article on "Women Scientists before 1920,"[3] women did function and function well in the sciences and up to around 1920 their numbers were increasing. However, from 1920 on, the tale becomes more dismal. It was not until the sixties that the numbers of women in these disciplines began to increase again in a substantial fashion. Precisely why this was so, had to do with the changing nature of science and the changing societal values of this particularly complex period of history. For the sake of presenting the material relating to our investigations more clearly, this era is subdivided into three sections: the nineteenth century (up to about 1920), 1920 to the end of World War II, and finally the post-war years up to around 1970. This period is conceived of as starting with the closing days of World War II and ending around 1970. During this era, several events took place that profoundly affected the participation of women in science and engineering. It was during this time that World War II radically altered the nature of science and technology and indirectly altered the role of women; the Civil Rights Movement began, the first feminist movement for all practical purposes died out and a second one began; and finally, governmental action to eliminate barriers to the full participation of women in all areas of work was started.[4]

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[3] Rossiter, Margaret, "Women Scientists in American before 1920," American Scientist, Vol. 62, May-June, 1974, p. 312-323.

In addition to this major era, three other periods of western European history seemed of significance in understanding our heritage of attitudes and practices regarding the role of science and the role of women and most especially the role of women in science. These three periods are: the period of Greco-Roman civilization or Classical Civilization, the period of the Middle Ages and the era known as the Scientific Revolution (the precise dating of the latter era is especially controversial, but for our purposes the Sixteenth through the Eighteenth centuries have been considered.)

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[4] One of the factors that played a decisive role in the second feminist movement was the Civil Rights Movement of the Sixties. Though specific documentation is not included in this paper, it should be kept in mind that women who participated in the Civil Rights Movement, then often moved on to become involved in the so-called Women's Movement. Moreover, the decade of the Sixties is generally considered to be crucial to the heightening of the consciousness of many "marginal" groups in our society.

The justification for treating such an immense span of history in such a topical and thematic fashion is that our purpose is not to set out all the history of women in science but rather to point to aspects of the role women in this particular set of endeavors that have their origins in certain attitudes and practices of these previous periods.

At present, we use such terminology as natural (or hard) sciences as opposed to the social (or soft sciences), professional, technology, applied science -- the list of words and phrases that form a constellation around the words science and scientist is quite large -- and all of them mean different things to different people. In our examination of periods more remote from our own, the terms were fewer but the definitions are more difficult for us to comprehend because despite the fact that the origins of science lie in these periods, the concerns of our "forefathers" were quite different. When one attempts to set forth a clear and succinct set of ideas about the role of women in science and in society, it is quickly apparent that this is even more difficult. So what will be attempted is to give some sense of what people in these periods thought and felt and meant when they wrote and talked about such concepts and to show how these shifting meanings relate to our own present set of dimly perceived values about these vital topics -- women in society, women in science and science itself.

Emily Putnam begins the Introduction of her book, The Lady, with the statement, "The lady is proverbial for her skill in eluding definition, . . ."[5] So, too, is the woman scientist. In every era, the conception of both the lady and the woman scientist varies as the society changes. For our purposes, historically, a woman scientist was one who engaged in one of the scientific disciplines that most nearly correspond to our notion of scientific discipline in a more or less organized way.

A final caveat, while most people in the eras we have chosen for examination would have an understanding of the term, lady, the term woman scientist would have very little meaning. This is what is meant by marginality.

This then is how this part of our investigation started and the assumptions that undergird it. It should be evaluated with this background in mind. It is in part a re-reading of some of the "record" and some of the interpretations of the "record" that seem to us to be pertinent and to offer some insight into our main area of investigation and as part of the steps toward understanding the role of woman throughout the past in the sciences.

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[5] Putnam, E.J., The Lady, Studies of Certain Significant Phases of Her History, Chicago, 1969 (first publication, 1910,) p. xxvii.

SECTION 2

Women, Science and Society In The Nineteenth Century

"Never was the sense of the virtuousness of technology more vivid than in nineteenth-century America. In 1853 an English mission exploring the sources of industrial success on this side of the Atlantic concluded, in awed tones, that 'the real secret of American productivity is that American society is imbued through and through with the desirability, the rightness, the morality of production. Men serve God in America, in all seriousness and sincerity, through striving for economic efficiency.' Clearly this Victorian investigative team did not know that they were observing an attitude that had been held by the common medieval and puritan ancestor both of themselves and the renegade colonists. . . ."

Lynn White
"Technology Assessment from the Stance
of a Medieval Historian"

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Women, Science and Society In The Nineteenth Century

Introduction

The nineteenth century in its own way was as revolutionary as the twentieth century. It was a century of great social change and this fact is reflected in the development of science institutionally, the changing status of women in society, and the entrance of women into education and the field of science on an organized basis in Europe and the United States. Moreover, it is in the nineteenth century that the institutions such as science, here in the United States, assume a distinctively "American" character.

While the nineteenth century was a great period in the history of science, American contributions were notable rather than predominant or pre-eminent.[1] Among the reasons for this, the most obvious one is that it was in this period that the pursuit of science and engineering was begun in a formal way. As a result, the institutional development of American science is of greater interest.

The tensions between pure or basic science and applied science and technology still apparent today was a constant theme throughout the nineteenth century. Traditionally, Americans have extolled the virtues of applied science at the expense of basic science (although basic or "pure" science firmly established itself in the late nineteenth century,) but even today, the question of the relationship between theoretical sciences and applied sciences in technology, medicine and agriculture, for example, is still an open one. Nevertheless, science in the United States came of age in the nineteenth century.[2]

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[1] Reingold, Nathan, Ed., Science in Nineteenth Century America, A Documentary History, New York, 1964, p. 4.

At the same time, the nineteenth century was a momentous one for women. For one reason, it is in this century that the struggle for full equality was begun in an organized way.[3] Also, during the nineteenth century higher education came into its own and women began to be admitted to institutions of higher learning. The result of this was to extend, to a limited extent, the vision of women becoming scientists in an organized rather than a haphazard way as they had done up to this time.

Another antecedant of the changing status of women in the nineteenth century in the United States was the hiring of young unmarried women to work in the mills of Lowell, Massachusetts (c. 1830). Though they were hired because they did not have to be paid so much and were supposedly much more tractable than men, the potential impact of this opening for women is implicit in an anonymous Lowell mill girl's defense of the "Dignity of Labor."

> From whence originated the idea, that it was derogatory to a lady's dignity, or a blot on the female character, to labor and who was the first to say sneeringly, "Oh, she works for a living?" Surely, such ideas and expressions ought not to grow on republican soil . . . . To be able to earn one's own living by laboring with the hand should be reckoned among female accomplishments; and I hope the time is not far distant when none of my countrywomen will be ashamed to have it known that they are better versed in useful than they are in ornamental accomplishments.[4]

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[2] Reingold, Science in Nineteenth Century America, p. 4.

[3] Mary Wollstonecraft's "Vindication of the Rights of Women" (1792) was the first feminist document to have an important effect on women in America.

[4] Quotation from Nancy F. Cott, Ed., Root of Bitterness, Documents of the Social History of American Women, New York, 1972, p. 13.

When the ideas of equality for women, education for women, and the dignity of work (outside the home) converged as they did in the latter half of the nineteenth century, the results were important for the role that women in the United States occupy at present. This is not to suggest that the status of women was completely altered. This was not the case. However, because of the rhetoric and agitation on behalf of the change in women's status in all respects, the question of the role women should occupy came to occupy a permanent, if variable, position in the fabric of American life.

In conclusion, as the discussion in some detail of these topics will show, the nineteenth century (especially the latter half) was time of tremendous change for women, science and scientists. Certain trends were established that to a large extent play a role in our attitudes toward all three today.

Nineteenth Century Science in the United States
(1789 - 1920)

For our purposes, the study of nineteenth century American science is of importance because during this century the question of the participation of women in the sciences became a topic of widespread interest and importance. As the sciences grew and women sought a recognized place in that form of endeavor, the question became a struggle which was to continue into the twentieth century. This topic also illuminates important beliefs of Americans about the role and nature of the sciences which played a part in development of the role of women in our society and in science.

There are additional reasons for analyzing the development of scientific institutions in United States but, in general, one of these reasons is not to recount the great role American science played in the scientific world at large.

While the nineteenth century was a great one in the history of science, American contributions, though notable, were not predominant or pre-eminent in terms of the general advance. The reason most often advanced is that American attitudes toward science and the role it plays in our civilization became evident at that time and still persist. What is good and what is bad in American science arise from this past heritage. A brief statement of the essence of that heritage is that its chief virtue is the ability to utilize knowledge for practical ends and its chief vice is a neglect of basic science. This observation was first made by the Frenchman, de Tocqueville.

Using this approach nineteenth century American science merits study because it illuminates a major aspect of the American national character or style and clearly explains trends in our history. Yet, this traditional interpretation implies another -- that science advances best when divorced from applications (this is a subject of debate); from this still another question arises. What is the relation between theoretical sciences and applied sciences in technology, medicine and agriculture?[1]

At the beginning of the nineteenth century (which really means the end of the Revolutionary War for United States scientific development) there was a lively interest in scientific matters in America. American science in this period was pragmatic, largely carried out by amateurs and catholic in the sense that the scientific disciplines were not clear-cut and many people of many different backgrounds engaged in many different types of scientific activities. Moreover, under the impact of the Revolutionary War there was a patriotic or nationalistic feeling toward the development of science in the new republic. This feeling can be described best as a passion for the idea that Americans ought to develop their own science and scientific institutions and not rely on Great Britain, in particular, for the development of their scientific institutions. It was also felt that just as the republic was the best form of government for political development so it was the institution best able to develop American science.[2]

By the end of the century such characteristics were largely anachronistic. American science had become specialized, institutionalized, professionalized, and nationalized. But the new republican government played a minor role in this development. The pragmatic strain in American science had been channeled into such areas as applied science, technology and engineering. Also, while in the earlier part of the century there was a tradition of activity in science, there was not, until later in the century, a scientific milieu or a scientific community, that would enable pure or basic science and scientists to flourish.

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[1] Reingold, Nathan, ed., Science in Nineteenth Century America, New York, 1964, p. x.

[2] Daniels, George H., Science in American Society, A Social History, New York, 1971, p. 126-127.

Alfred North Whitehead, writing shortly after World War I, could say that the union of science and a passionate interest in detailed facts with equal devotion to "abstract generalization" had produced "a balance of mind" now part of "the tradition of which infects cultivated thoughts."[3] This was as true in the United States as it was in Europe. While trying to follow the European pattern in some respects and at the same time evolving its own unique institutions, by the end of World War I, American intellectual life, and had reached a point where new and more original developments could be made.

At the same time, throughout the nineteenth century but especially from the time of the Civil War spectacular advances were made technologically, most of them by Europeans, and adapted to American uses by Americans. Technology found a favorable environment in the United States and Americans built an industrial complex that was the most outstanding yet seen. As Lynn White, Jr. points out:

> Never was the sense of the virtuousness of technology more vivid than in nineteenth century America. In 1953 an English mission exploring the sources of industrial successes on this side of the Atlantic concluded, in an awed tone, that 'the real secret of American productivity is that American society is imbued through and through with the desirability, the rightness, the morality of

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[3] Barzun, Jacques, Science: The Glorious Entertainment, New York, 1964, p. 5 (paraphrased).

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> production. Men serve God in America, in all seriousness and sincerity, through striving for economic efficiency.[4]

An observation about these developments and the environment that fostered tham is in order at this point. A thoughtful reading will indicate that pure science of Whitehead's "abstract generalization" did not exactly go hand-in-hand "with a sense of the virtuousness of technology." Though the institutions that fostered both these developments in American life had been erected in the nineteenth century, the climate of popular opinion favored, as the Englishmen observed, production and what would foster production. The two climates of opinion about what was important in science and the two quite different approaches to science existed side-by-side in uneasy coexistence.

American science remained a part of the general development of science in that it underwent all the changes that were occuring in science's institutional aspects everywhere in the Western world at a different pace and in a distinctively American way. As a result, women interested in participating in the scientific world were forced to contend with the growing rigidity that came about because of developments in the scientific community in the late nineteenth century.

The most important of these events were: the growing dependence of science on national institutions for support, an increasing fragmentation into specialties and into new forms of science, the development of professionalism within both science and technology, the growing separation between basic and applied science, and the emerging large-scale industrial laboratories.

At the same time, the international character of science remained more or less intact until World War II despite the rise of nationalism and the shock of

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[4] White, Lynn Jr., Technology Assessment from the Stance of a Medieval Historian," American Historical Review, Vol. 79, No. 1., February 1974, p. 2.

World War I. Indeed, it was source of pride to American scientists that they belonged to this elite world which knew no boundaries and in which discoveries, theories, and other scientific contributions were shared. American participation in this larger world can be evaluated by reading the correspondence between American and European scientists contained in Reingold's collection of documents relating to the development of nineteenth century American science.[5] As a result, despite a growing nationalism both here and in Europe and despite the efforts of Americans to improve the quality of American science, the dependence of Americans on European contributions in both science and technology was fostered. Alexis de Tocqueville, who commented on the lack of American interest in abstract science also pointed out that the availability of Eurpean research removed the necessity of the repetition of such work in the United States.[6]

One of the major developments in the growth of basic scientific research in the United States was the formation and expansion of national institutions on which science and the scientists became dependent. These institutions, though inspired by developments in Europe, soon developed uniquely American characteristics. Among these institutions were: the Smithsonian, the National Academy of Science, the American Association for the Advancement of Science (and its forerunners) and the universities.[7]

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[5] Reingold, Science in Nineteenth Century America, (examples of nature of the relations between Americans and their European colleagues are contained in the collections of correspondence presented in the book.)

[6] Dupree, A. Hunter, "Influence of the Past: An Interpretation of Recent Developments in the Context of 200 Years of History," The Annals of the American Academy of Political and Social Sciences, Vol. 35, January 1960, p. 21.

Among American national institutions that played active roles in the development of the basic science in the United States and thus encouraged the dependence of science upon them was the Smithsonian Institution. Founded in 1946, it developed a program of fostering basic scientific research largely as the result of the efforts of its first secretary, Joseph Henry, a physicist. His goals throughout his more than three decades as secretary were centered on implementing the literal interpretation of Smithson's bequest -- to assist the increase and spread of knowledge by promoting original research of the highest character aimed at discovering general principles or laws of nature and publication of a series of memoirs.[9] As a result of his administrative skill and efforts, the Smithsonian amply fulfilled Henry's goals and became an important influence in the development and dissemination of the results of American scientific research. Though many of the activities of the present-day Smithsonian, such as the museums, fall outside Henry's ideal, the Smithsonian continues to play an important role in science.

While not exactly a national institution, the Lazzaroni deserve to be included in a discussion of forces that affected the development of American science and of national institutions that supported. The "Lazzaroni" or (scientific beggars) met informally and corresponded and gathered at the meetings of another emerging national institution, the American Association for the Advancement of Science. Most of the Lazzaroni were geophysicists but their research interests were wide-ranging and their influence spread to all the sciences, but not without opposition. Their somewhat elitist position did not sit too well in a new republic. Their achievements can best be summed up by stating their aspirations -- they were consciously developing a professional scientific community.[10]

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[7] The dates at which women became members vary and will be discussed in the section on Women in 19th Century Science.

[8] Bates, Ralph, Scientific Societies in the United States, 3rd edition, Cambridge, Mass., 1965, 1st publication 1945, p. 71.

[9] Bates, Scientific Societies, p. 71.

Another national institution came into being during the Civil War without much public notice. A National Academy of Sciences, the dream of Jefferson, became a reality under the adroit maneuvering of one faction of the Lazzaroni. As any organization must have a purpose, the Academy was to advise the federal government on scientific affairs. The Academy ran into opposition among scientists and neglect on the part of the government and might never have survived without some outside financial support in its early period.[11]

The Lazzaroni received help in the form of direct political guidance through Congress from Charles H. Davis, Chief of Navigation of the Navy Department, in 1863. Under the terms of its incorporation fifty outstanding scientists were to be incorporators. As it turned out, thirty-two were in the physical sciences (mainly geophysics) and eighteen were in natural sciences. Moreover, twenty-two of the incorporators were in some way connected with the federal government. Though this composition reflected the desires of the inner group of the Lazzaroni, it did not reflect the true state of science in the United States at that time, in terms of scientific work being performed. The natural scientists were neglected, and the high percentage of government employees was atypical of United States science at

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[10] Reingold, Science in Nineteenth Century America, p. 200-203.

[11] Reingold, Science in Nineteenth Century America, p. 200-202.

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that time. However, the high percentage of government employees was beneficial, for then as now, federal funds were desirable. The general composition of the original fifty then were ascribed, correctly, to the preferences and animosities of the inner group of the Lazzaroni, and some outstanding researchers were left out.

The real significance of the founding of the National Academy of Sciences was that nothing happened directly as a result. Most other national academies were strong forces for research in their countries. But in America no one powerful scientific body came into being. Neither the Academy nor the American Association for the Advancement of Science (AAAS) ever dominated the scientific scene. Between the Civil War and World War I, national organizations for specific scientific fields appeared — the scientific societies -- and they soon controlled the publication of research results and the establishment of professional standards. (They will be discussed under the topics of professionalism and specialization.) The period, 1865-1914, can be described as one of slow steady growth in science in America unaided by massive infusions of public funds and without overall planning. Lack of funds pinched many scientists; the absence of planning resulted in odd patterns of strength and weakness -- too many observatories and not enough physics laboratories to give an illustration. The Lazzaroni represented establishment science and elitism. Backed by federal funding and direct planning their predilections might have altered the growth of American science. They were receptive to innovation, but only within limits as is true of anyone. Unhampered by restraints imposed by more openly bureaucratic systems such as those that prevailed in Europe, American science developed a tradition of wide-ranging, relatively unconfined research that depended largely on the university, the professional society and private funding for its orientation and its selection of problems. This tradition of unfettered pure research is a basic element in American science.[12]

There were two forces that reacted upon one another to contribute to nationalizing, professionalizing and specializing of American science at one and the same time. These were the university, which changed in response to the demands of the sciences and technology and the national society organized within one profession or specialized field of science. The latter, along with the broad-based national society devoted to all the sciences grew out of an older institution -- the learned society. The professional society played a direct role in developing American science. On the other hand, the broad-based national society provided a forum for all the sciences where those who were interested could hear of the latest developments in this discipline and offered a meeting ground where scientists might interact with one another.

The concept of a national learned society devoted to all aspects of the sciences where followers of science could read papers and discources on topics of mutual interest much like the Royal Society of Great Britain appealed to people like Benjamin Franklin and Thomas Jefferson. However, attempts to establish such a society in the early days of the republic failed. In its place, local groups began to appear. Two of these, founded in the last half of the eighteenth century,survived and partially fulfilled the function of a national society.

The first of these, the American Philosophical Society, was founded either in 1743 or 1744 under the aegis of Benjamin Franklin and the second, the American Academy of Arts and Sciences in Boston was formed in 1780. Originally, the interest of the Philosophical Society (based in Philadelphia) was broadly defined -- to discuss questions of "natural philosophy, moral sciences, history, politics" and to carry on "investigations in botany; in medicine; in mineralogy and mining; in mathematics; in chemistry; in mechanics; in arts, trades, and manufactures; in geography and topography; and in agriculture."[13] The aims of the Academy were similarly broad.

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[12] Reingold, Science in Nineteenth Century America, p. 202-203.

Despite the formation of many such learned societies throughout the period of the early republic and in many places including the capital, most were short-lived and unable to live up to their noble aspirations. However, they were indicative of the wide-spread interest in science both on the part of practioners and laymen.

The first successful and truly national forum for scientists and in a different way for laypeople was the American Association for the Advancement of Science which was formally established in 1848. Its aim was two-fold — to provide a national rostrum for science and at the same time to provide the framework in which individuals doing research could interact.[14] Throughout the period prior to the Civil War there was a membership of about six hundred annually with an additional one hundred and thirty or so who participated in the meetings without becoming members. At least 25% of the founders remained active for the entire period; thus sustaining as well as establishing the AAAS. Meetings had from eighty to three hundred participants depending on the location and up to one-fourth of those attending participated actively either by serving on a committee or presenting a paper. The section meetings varied in size but mathematics and physics, geology and geography, chemistry, and natural history were the most well-represented.[15]

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[13] Bates, Scientific Societies, p. 71

[14] Kohlstedt, Sally G., "The First National Forum for Science: The AAAS, 1848," paper presented for oral delivery at the AAAS Meeting, San Francisco, March 1, 1974, p. 2. Quoted with author's permission.

The problem faced by the founders of the AAAS, principally the Association of American Geologists and Naturalists, but also including the ever-present Lazzaroni, was how to expand and become a national forum without moving away from specialization (which some would consider a regressive step.) The founders felt the section meetings would fill the demand for specialization and all the sciences of the British Association for the Advancement of Science.[16]

The organizers "regretted the growing specialization in science even as they recognized its inevitability. They advocated government sponsorship for research, worked for better scientific education, wanted a specific code of scientific ethics (which apparently was never completed,) and recognized a distinction between scientists and amateurs."[17] These conflicting aims were never resolved. Yet, it is perhaps a tribute to the founders of the AAAS that they were not. As a result of their inability to solve this issue they both fostered better practices of science within the disciplines and maintained a forum for better practices of science in general. In these ways, the AAAS has played an important role in American science since its foundation.

The final institution with a national scope to be analyzed in terms of how it helped further the professionalization and specialization of American science and engineering in the nineteenth century is the university. There are other institutions such as the government and the private foundation but their role was important for the direction twentieth century science took. The role of the professional society will be considered in the discussion of the development of professionalization and specialization. At this point, it is difficult to separate the development of professionalization and specialization from the rise of the professional society and the change in the universities. But the development of the university in response to the changing structure of science was exceedingly complex because the university had been founded in response to one set of needs and was changing not only because of the demands of science but also because of new social expectations.

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[15] Kohlstedt, "The AAAS, 1848," p. 2-3.

[16] Kohlstedt, "The AAAS, 1848," p. 4.

[17] Kohlstedt, "The AAAS, 1848," p. 11-12, 13-14.

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The role of the universities will be examined from the point of view of what scientists in the nineteenth century sought from them and the problems scientists and universities encountered when attempting to meet these expectations as well as demands of others outside the fields of science and engineering.

Scientists are dependent on the institutions which house them and give them support, however much their individual reputations outshine their institutional setting. During the major part of the nineteenth century science and scientists were in the process of polarizing around an already established national institution -- the university. As a result, the older American traditions of humanistic learning and religious orientation on which the university was founded began to change.

Originally, colleges had been modelled after the English university and offered an education in the traditional liberal arts, Greek, Latin, Mathematics, and Philosphy with, in many cases, religious training as well. The private college movement which began before the Revolution with the founding of nine degree-granting institutions of this type developed rapidly until the Civil War. By then, there were approximately two hundred private colleges - most of them established by religious institutions. Persons who sought additional training in the sciences usually went to a medical school which served as a substitute for a graduate school or went to a school offering technical courses such as West Point or Rensselaer Polytechnic which were just beginning to be established.[18]

In the United States, imposed on this developing system of private colleges was a new system of secularized public institutions. This was the result of the revolutionary influence which was dedicated to the ideal that education should be democratic and free and devoted to advancing the ideals of equality and freedom. At first, the states had tried to make the private colleges public universities but that failed when the Supreme Court ruled against them in 1819. The states then began to establish their own institutions with public control and public support. During the Civil War, this movement received federal support with the passage in 1862 of the Land Grant Act which provided support to establish agricultural and mechanical colleges in the states. Some states used these funds to strengthen already existing universities; others established separate agricultural and engineering colleges.[19]

The scientist, who had outgrown the amateur model of the British tradition and was developing into the academic specialist similar to the German model, turned to the university to achieve his goals of professionalization and specialization. What he wanted was graduate training leading to the doctorate and rigorous courses in the various scientific specialties. Such a program was a necessary first step to professionalization. Yale was the first American university to establish a continuing graduate program leading to the doctorate. But Johns Hopkins, established in 1867, modeled after the German university, and devoted to higher education and research marked the real beginning of the alliance of the research-oriented scientist, eagerly pursuing his specialty and the university whose goal was to provide him a setting for his work and produce more people like him.[20]

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[18] Reingold, Science in Nineteenth Century America, p. 3-4, p. 315-316; Dupree, "Influence of the Past," p. 22; Degler, Carl N., Out of Our Past, New York, 1959, p. 19-20, p. 157-160. Interestingly enough, Renssalaer contains in its charter that it was for the "sons and daughters" of the people of New York.

[19] Degler, Out of Our Past, p. 157-160.

Within the technological and engineering colleges the trend toward specialization and professionalization can be followed in the splitting off of civil engineering from military engineering and the further subdivision into civil, mechanical, electrical and chemical engineering. Within the field the requirement of a fifth year of training and a thorough grounding in all the engineering before specializing. The doctorate as part of the process of becoming a professional engineer did not become prevelant until just recently.[21] As is shown in Table One, there was a rapid proliferation of institutions with graduate programs in science and engineering.

Though the general scientific society and the university played crical parts in the professionalization of American science, the impact of the professional scientific or engineering society was decisive and unique. Through the professional society, composed of members drawn from a specific scientific discipline and meeting the standards imposed by that society, it became possible to organize specific disciplines in such a way as to exclude those who lacked the requisite education, training and any other qualifications deemed necessary to be considered a "professional" within the particular scientific or engineering field. In turn, such standards helped shape the curricula offered by the universities.

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[20] Bates, Scientific Societies in the United States, p. 15-27.

[21] "Engineering Education in the United States," Encyclopaedia Britannica, Volume 8, Chicago, 1957, p. 445-446.

An important factor in the appearance of the professional society was specialization within the sciences. This trend was a vital part of the scientific development of the late nineteenth century, but the fragmenting of science into sub-fields began in the late eighteenth century. Medicine, agriculture, chemistry, minerology and various technological fields were among the first to form professional groups.[22]

One of the ways that the specialized society was able to form a new discipline and to unify it was through the publication of scholarly journals. Another was the holding of professional meetings, similar to those of the AAAS, but devoted to presenting papers and holding discussions related to the particular scientific field. In other words, the professional society not only encouraged and actively promoted the setting of standards to qualify for admission to the particular field, it also supported the trend to narrow specialization. The rapid development of learned societies between 1800 and 1900 is shown in Table II.

It is, however, important to remember that the national professional societies, the universities offering specialized scientific training and the general scientific societies mutually reinforced the trend of expansion and diversification within the institution of science. Moreover, and this point will be dealt with when considering the role of women in science during this era, such a trend as this had the effect of "freezing out" generalists and people whose qualifications were minimal and those who could not gain admission to the establishments of science and engineering.

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[22] Daniels, Science in American Society, p. 274-276.

By the end of the nineteenth century, the goals and needs of professionals and specialists within the expanding sciences were in conflict with the values of four different groups of people who were involved in higher education. The first group consisted of the governmental bodies involved in funding and administering the development of the new programs for higher education -- both state and federal. The second group consisted of scientists devoted to the "generalist" approach to the study of science. In general, these people belonged to the older generation of scientists. The third group was the public. Prior to the 1870's science had been successfully "sold" to the public in terms of its contribution to important American values -- utilitarian, equalitarian and religious. This new ideal of the scientist and his role in society embodied in the concepts of professionalization and specialization and the slogan "science for science's sake" received powerful reinforcement from the new graduate programs in science. Though "pure" science and its value system prevailed within the university and within the sciences, it never really appealed to the public or the government and they only reluctantly went along with it.[23] The fourth group were women - women eager to partake of education at all levels and pursue scientific careers. Their concerns and accomplishments have to be evaluated not only from the point of view of the institutions they wished to be a part of, but also from the point of view of the attitudes of the public toward science and scientists. However, a general observation can be made at this point. The effect of professionalization and specialization made it even more difficult to enter the "scientific world."

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[23] Daniels, Science in American Society, p. 317-318.

In the late nineteenth century, increasing numbers of scientists in the United States were to be found in two other kinds of institutions that have not yet been mentioned. Both of these increased in importance as users of scientists in the twentieth century. One of these was especially significant - the large scale industrial laboratory. Science has come to be reorganized on the lines of large-scale endeavors involving large numbers of people and a greag deal of equipment. Though we tend to ascribe this development to the influence of the two world wars, its first impetus along those lines came from the great industries that emerged in the late nineteenth century.[24] While at first concerned with applied science problems the concept was gradually taken over by those working on problems in basic research. As a result of a period of consolidation and regular growth it became possible to think of organizing industrial research laboratories. Chemical laboratories were the first to be organized. (This had been done in Germany in the early nineteenth century.) Electrical laboratories such as the one founded by General Electric in 1900 were also among the first to appear. Appearance of such laboratories in such areas was indicative of two things: they were more likely to appear in the "newer" industries and among firms that were stable and with sufficient resources.[25]

The other -- the governmental bureau -- had expanded into scientific research as a result of the problems posed by the Civil War. The research done in organizations like the Coast Survey and the Bureau of Agriculture was in the area of applied science as might be expected and there was a growing demand that anything that did not yield immediate and practical results be eliminated from the programs of these governmental institutions. This conflict was also illustrative of the growing suspicion of pure science and the isolation of the new scientist from the mainstream of public opinion on the subject of science.[26]

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[24] Daniels, Science in American Society, p. 319.

[25] Daniels, Science in American Society, p. 281-283.

To summarize -- the scientist on the eve of World War I was a new creature with the following characteristics: (1) A new professional consciousness focused on the discipline within which he was trained. Approval was sought from colleague rather than from society and success meant acceptance by disciplinary peers. The scientist was impelled to publish to obtain this approval but in order to publish he needed to do research and to do research he needed support. As a result, he was forced to depend upon institutions whose controls he did not want to recognize, The dilemma between independence to pursue his own interests and the need for support persists today. (2) A different kind of approach to the world of science. His training had prepared him for pursuit of a professional occupation and he had abandoned the notion that science was part of a liberal education and consisted in acquiring the scientific spirit and the scientic method.[27] It should be added that this scientist was white and male. Very few outsiders (including women) penetrated this preserve.

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[26] Daniels, Science in American Society, p. 280 -281

[27] Reingold, Science in Nineteenth Century America, p. 251-252.

Women in Nineteenth Century America

> Probably no aspect of our time is more significant of progress than the ever-growing discussion of place and duties of women in the social state. Causes both economic and moral have tended to break up old habits of life and thought, and make new demands upon their capacity and conscience, which experience has not yet taught them to satisfy. All over our land, women are conscious of a ferment and disturbance of thought which is the prophecy of better things. Everywhere they are asking, ' What can I do to hasten the New Day?'[1]

The quotation which introduces this section epitomizes very well the fact 'something was in the air' in the late nineteenth century with regard to the role of women in society. Throughout the nineteenth century, the status of women changed a great deal and this was in part a response to a changing social situation.

A drive for equality by diverse groups of people characterized this period in American history. Beginning with the abolitionist movement, which culminated in the Civil War and Reconstruction, and the first feminist movement to be called later the suffrage movement, were only two of the more important aspects of the drive for equality. The expansion of education and the attempts to integrate immigrants into the main stream of American life were other aspects of this phenomenon. The lure of the frontier and the expanding industrialism of nineteenth century American (with the beginnings of the drive to unionization) also contributed to widening people's horizons and changing the ways people had traditionally lived. The result was that the nuclear family became the unit that took most of the pressure of this social change and because of the important role of women in such a family, the image of the ideal woman hardened into forms implicit in earlier centuries. This change began in the early nineteenth century but reached its perfected form in the late nineteenth century at the same time women really began in coherent fashion to attack this "vision of reality" and press for changes in their "real" circumstances.

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[1] Phelps, Elizabeth Stuart, et al., Our Famous Women, an Authorized Record of Their Lives and Deeds, Hartford, Connecticut, 1884. Publishers preface: This book contains a series of biographical sketches of notable women of the period written by equally notable women and published privately. The only persons who could be classed as in the science-related professions included Clara Barton, nurse; Maria Mitchell, astronomer; and the Blackwell sisters, physicians. The emphasis was on writers, abolitionists and suffragettes.

In a book entitled *American Feminists* published in 1963, Robert E. Riegel attempted to evaluate the feminist movement of the nineteenth century. His aim was to right what he considered to be imbalances in the scholarship on the subject up to his time concerning the American feminist movement. In no way can his book be considered a balanced picture of the development of this era. Rather, it is a series of biographical sketches interspersed with his comments about the "realism" of the feminists and their many drawbacks as people and leaders. His aim is summed up neatly in his conclusion. He presented a picture of the feminist in contrast to:

> . . . the traditional attitude [which] was that feminists were highly intelligent women who were inspired to action entirely by the terrible condition of women, and devoted their lives unselfishly to assist the millions of unhappy members of their own sex. *In the process of developing this generalization the troubles of women have been vastly overstated, the attitudes of both men and women have been misinterpreted and the psychology of the feminist*

> were misunderstood. Feminists were highly talented, but they were also real human beings with normal human emotions. Just like others, they were deeply influenced by their environment and particularly by their home problems, sometimes greater and sometimes less than those of the average human being. These factors of personality and environment were vital in determining the women's lives, and the very human frailities of the feminists make them more fascinating and even more admirable than the lawless but wooden figures of a poor novel.[2]

Riegel's book is interesting and important for the following two reasons. One, as the above quotation shows even in 1963 the nineteenth century feminist movement was [and is] not without its detractors. The emphasis Riegel placed throughout his descriptions of the first feminists is, as the quotation shows, on the importance of feminists' psychological makeups and family backgrounds and their "supposed" misconceptions of the actual situation of American women in the nineteenth century. This view is, or was not, new. It had been first enunciated in the nineteenth century in response to the challenges of the feminists and took the form of a romantic and visionary view of the role of the family and of women that was everywhere presented for the consumption of middle-class nineteenth century men and women. The interesting thing, as will be shown, is that the feminists adopted parts of this visionary and romantic view of what the role of a woman was and based part of their justification of why women should have equal rights on it.

The other reason for the importance of Riegel's book lies not in his interpretation of the nineteenth century American scene as it related to women but rather in the fact that his book was published in 1963, the same year as Betty Friedan's Feminine Mystique. As was demonstrated by the 1960s, there existed a fairly substantial body of literature that in one way or another vindicated the nineteenth century feminists' view of the condition of women in general, and moreover, showed that despite the increasing participation of women in the world of work and the world of education, the woman from whom the feminists had expected so much -- the middle-class woman -- had indeed not achieved true equality in any area of her life and had not participated to any great extent in the mainstream of American life. This was in part true because writers such as Riegel (or his nineteenth century counterparts) on the one level and the popular publications (such as women's magazines) from the nineteenth century on reinforced the romantic image of the utterly feminine woman who hald together the perfect family and thus made her greatest contribution to society within the family structure.

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[2] Riegel, Robert E., American Feminists, Lawrence, Kansas, 1963, p. 201. Emphasis added.

In order to arrive at some insight into the inter-relatedness between the popular view of women and the feminist conception of women and the effects of these on women themselves have to be examined. Because most of the debate was centered around the role of middle-class women and it is from this group professional (including scientists) women in large part come,[3] a caveat must be made that writers (both feminists and non-feminists) presented biased views as they related to the role of women in general in some respects. There is a great deal of literature on the subject of the social origins of women who pursue the sciences. If the entries in Notable American Women, the portraits presented by Mozans and Osen as well as evidence presented about the background of twentieth century women scientists are assessed rather carefully[4], then the preponderance of such women came from middle-class rather than upper or lower middle-class origins.

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[3] There have been scholarly works in this field such as the following: Elmira L. Phelps, Notable American Women (3 Vols., 1971); Sally G. Kohlstedt, "In Pursuit of the Amateur Tradition: The Boston Society of Natural History." The section that is relevant to women is found p. 14-18. Paper presented at Radcliffe Institute, April 26, 1974. Cited with author's permission; Thomas Woody, A History of Women's Education in the United States (1929), reprinted, 1966, 2 Vols.; Edna Yost, American Women of Science, Philadelphia, 1942, studies eleven women scientists; Margaret W. Rossiter, "Women Scientists in America before 1920," American Scientist, Vol. 62, May-June 1974, p. 312-323; Nancy F. Cott, Ed., Root of Bitterness, New York, 1972. Documents from the nineteenth century. Does not deal directly with science but with the conditions of the nineteenth century America; Mary R. Beard, Woman as Force in

The feminists who gathered at Seneca Falls in 1848 were far removed from the mainstream of American life. Whenever those who were abolitionists spoke in public or distributed pamphlets, they were criticized for departing from proper feminine behavior.[5] Because of the censure of their behavior and because of their exclusion from the abolitionist meetings, these women and others joined together to demand equality for themselves.

Their original argument, as based on the 1848 Declaration, was that there should be a drastic change in the values and laws governing relationships between

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History, first published 1946. Wideranging, but has sections on the nineteenth century; H.J. Mozans, Women in Science, New York, 1913. Recently reissued. Indispensable but some of his evidence and conclusions about pre-nineteenth century Europe should be treated with care.

[4] Phelps, Elmira Lincoln, Notable American Women, (3 Vols. 1971): Mozans, Women In Science; Osen, Lynn M., Women in Mathematics.

[5] Chafe, W.H., The American Woman, Her Changing Social and Economic and Political Roles, 1920-1970, New York, 1972, p. 3-4.

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the sexes and they also attacked all forms of discrimination. Implicit throughout the Declaration was the view that, as long as society assigned separate areas of responsibility for each sex, women could never be free. "By insisting the men and women were identical in 'capacities and responsibilities,' the feminist attacked the fundamental premist underlying relations between the sexes -- the notion of distinct male and female spheres. Once it was established that the two sexes were alike in the eyes of God, there was no longer any basis for treating women as separate and inferior and the demands for equality in the church, state, and family logically followed."[6] The early feminists, and those who remained the most ardent feminists and, rejected suffrage as the main goal and felt that "if women were to achieve equality, they had to be able to pursue their individual desires and participate in all areas of life on the same basis as men."[7]

They based their arguments on the subjection which was enforced on women legally as taken from what Blackstone in his Commentaries said the common law said was the role of women. As Mary R. Beard has shown, though Blackstone, a very conservative man to begin with, did not say that the common law was the whole of English law (nor was it the whole of American law) as it pertained to women, he certainly put his main emphasis on it and because of Blackstone's elegance and simplicity, he became in most American minds, both lay and legal, the law as it pertained to women.[8] Beard quoted as an example of the popular version the lawyer,

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[6] Chafe, The American Woman, p. 6.

[7] Chafe, The American Woman, p. 9.

[8] Beard, Mary R., Woman as Force in History, p. 22-23.

Edward D. Manfield, who wrote "The Legal Rights, Liabilities and Duties of Women," published in 1845. In it, he recited the Blackstone ritual:

> As marriage creates a unity, he averred, "and the husband is religiously the head of the family, the law declares that the external powers of this family, in respect to property and government shall vest in the husband." . . . After a brief reference to the wife's rights in case of a trustee-ship, Mansfield proceeded: "this *merging*, as it is called, of the wife's property and person in the husband, has been called little less than downright slavery. In this respect the Roman law was much more liberal than the English law or American. For that law considered marriage as a sort of partnership, in which each partner had equal rights of property. *We consider here, however, not the propriety, but the facts of the law; in order that women may know what it is.*[9]

Before discussing the role of women in science in nineteenth century United States, a brief protrayal of the ideology of predominant mileu in which women functioned in that period will be set forth. Against that the work of John Stuart Mill on the role of women and themes predominant in the first feminist movement will be presented. The reason for doing this is two-fold. On the one hand, it is hoped that this will make clear the social pressures under which women worked both as scientists and as women. On the other hand, in so doing, the values presented should make clear that following Eileen Power's observation that the role of women is the test point of a society is especially appropriate when looking at nineteenth century American attitudes toward women.

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[9] Beard, *Woman as Force in History*, p. 23. Emphasis added.

Women Scientists in Nineteenth Century United States

Just as science was evolving and taking on characteristics that are found in science today, so too, the woman in science was assuming unique features that prevail today. The purpose of this section of the historical analysis of women in science is to set forth these characteristics and to show that extent of the participation of women, as much as possible given the fact that the history of nineteenth century American science is a new discipline[1] and the history of women in science is an even newer historical enterprise.[2]

The common assumptions about women in science and engineering seem to be that there aren't any, or very few at most, and that women have only recently begun to become a part of the American scientific community. The basis of these assumptions lies in yet another widespread belief -- that women are neither fit for scientific and technical careers nor interested in them.[3] It should be noted that these assumptions are held by women as well as by men. Moreover, these assumptions underlay the prevailing attitudes of the nineteenth century about the role of women in science. However, no matter how widespread these beliefs, then and now, none of them are completely true. What is true is that women in nineteenth century science existed and their career patterns, so far as they can be determined reveal that current patterns and problems for women in science have their origins in the career patterns and problems of women scientists of that period.[4]

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[1] George H. Daniels, Science in American Society, New York: Alfred A. Knopf, 1971, Preface, pp. ix-xi, passium.

[2] Barbara Sicherman, "American History: A Review Essay," Signs: Journal of Women in Culture and Society, 1975, vol. 1, no. 2, pp. 461-465, passim.

[3] Harriet Zuckerman and Jonathan R. Cole, "Women in American Science," Minerva, A Review of Science, Learning and Policy, vol. 13, no. 1, Spring, 1975, p. 84.

There are three studies, out of several that have recently appeared, that are pertinent to this topic, but increasingly, material is being discovered and works, in whole or in part, address themselves to this topic. The study of Margaret Rossiter has already been cited. The other two are those done by Rudolph C. Blitz and the publications by the American Associations of University Women on their fellowship program established in 1890.[5]

While statistical data is hard to come by and governmental agencies did not routinely keep or publish statistics on men and women in science until well after 1900, all of these studies are statistical, as well as interpretive, in approach and attempt to compare the place and patterns of women in science with those of men.

Margaret Rossiter relies primarily on the first three editions of James Cattell's American Men of Science: A Biographical Directory (1906, 1910 and 1921). Among the entries in these directories were 504 women scientists.[6] Not only did Cattell collect biographical information about scientists, he also attempted to assess the quality of the work done by the individual scientist.

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[4] Margaret W. Rossiter, "Women Scientists in America Before 1920," American Scientist, vol. 62 (May-June) 1974, p. 312.

[5] Rudolph C. Blitz, "Women in the Professions, 1870-1970," Monthly Labor Review, Volume 97, No. 5 (May 1974), pp. 34-39.

Ruth W. Tryon, Investment in Creative Scholarship, 1890-1956, Washington, D.C., AAUW, 1957.

As part of her study, Rossiter compares this group of female scientists with a group of 502 male scientists from the 1921 edition in order to establish a picture of male scientific professional patterns. Her overall findings about the career patterns of women are:

> Their situation is of contemporary interest, for many of the current problems of women scientists were present before 1920. Although their interests and backgrounds varied widely, they clustered in certain fields and institutions, and despite an average level of education higher than that of the male scientists, (in contrast to to today's situation) they had fewer job opportunities and lower status, were more often unemployed, and less often considered eminent by their fellow scientists.[7]

Table one presents the fields, doctorates, marital status and occupations of the 504 women scientists. From this table can be seen that the largest numbers of women were in the life sciences, the medical sciences and the emerging social science, psychology. The most popular fields for women today are the social sciences and the life sciences in that order. However, with the exception of psychology and anthropology, most of the social sciences had yet to be established prior to 1920. Another point to remember is that those women in the field of home economics were mostly chemists by training. Degrees in home economics without training in chemistry are of relatively recent origin. If the two fields are groups, then the number of women in chemistry is also quite high.

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[6] As Rossiter notes 504 entries do not constitute a complete list, but it is perhaps the most convenient for it does contain biographical information. Cattell obtained his lists from other biographical directories membership lists of 50 scientific societies, rosters of 70 institutions of learning, contributors to Science and an advertisement in Science. "Women Scientists in America Before 1920," p. 323.

[7] Rossiter, "Women Scientists in America Before 1920," p. 312.

By comparison, (Table 2) the numbers of men are distributed more evenly over a wider number of fields -- (14 as opposed to 11) and larger numbers tend to be in chemistry and medical sciences with relatively large numbers in engineering and the other physical sciences.

The same comparison holds true for other types of occupations. Women were overwhelmingly found in academic settings while men held jobs in a wider variety of settings though they too tended to gravitate toward the colleges. (Table 4) This comparison reflects one definite trend and suggests other possibilities. The preponderance of scientists, male and female, in academic settings illustrates concretely a trend pointed out earlier -- in the late nineteenth century, increasingly, scientific pursuits came to be associated with academe. If Table 3, showing the academic institutions employing women is examined, it becomes apparent that most women were to be found in women's colleges. However, if the list of institutions employing women (found in Table 3) is coupled with this observation, it appears that the number of institutions employing women almost tripled between 1906 and 1921. A partial explanation for this is the rapid formation of colleges and universities, both women's and coeducational and the establishment of departments and schools of home economics in the land grant colleges. As for male scientists, their wider range of fields and types of occupations would seem to suggest that more choices were available to them.

While it is not possible to compare marital status of the male and female scientists, it should be noted that most women scientists were unmarried. From this it would appear that the idea of combining a career with marriage and a family was even more difficult to pursue then and now. This is largely due to the societal values held by both men and women. These are discussed in another section of the historical analysis but one point is worth emphasizing. Despite the fact that the "suffrage question" was being hotly debated and the impression that the role of women was undergoing great change, relatively little actual change was occurring.

One other feature of Rossiter's analysis of the nature of the participation of women in the sciences before 1920 is her observation that despite the numerical increase of women listed in Cattell's directories -- 149 in 1906, 204 in 1910 and 459 in 1921, the percentages of women in scientific fields did not change all that much (3.6%, 3.5% and 4.8% respectively) because the number of male scientists was also increasing.[8]

Cattell has another purpose in compiling his directories. He wished to identify a group of 1000 top scientists and study them further. To do so he had scientists in each field rank each other and he "starred" the top 1000 in each of his volumes. Though it was easier for both men and women to be included in this group in 1906 than 1921 (reflecting the growing professionalism in science), it was much more difficult for women than for men. Thirty women were starred in one of the three editions -- less than half the 78 starred in the male sample. In addition, because the overall number of women scientists was increasing and the number of outstanding women remained relatively constant (19 in 1906, 18 in 1910 and 24 in 1921) the percentage of women who were starred dropped from 12.8% in 1906 to 5.2% in 1921. Cattell could not understand why -- when the world for women in science looked so bright. He considered two possibilities: 'some innate sexual disqualification' or the possibility, 'that the lack of encouragement and sympathy is greater than appears on the surface.'[9] Today, this would be considered a case of sex discrimination.

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[8] Rossiter, "Women Scientists in America Before 1920," p. 312.

The material presented by Tryon and Blitz emphasize the points made by Rossiter. Since their work is largely concerned with later period, a detailed analysis is not presented there. However, a final set of materials on the question of whether women should have a role in science and if so, what it would be should be briefly discussed. These range from comments such as those in the Scientific American in 1870 which considered the issue settled and opined that "...no intelligent, refined man who views things as they really are would seek to exclude them [women]. These occupations in no way injuriously affect the qualities admired by the other sex. They may and ought to be made as remunerative to women as to men now engaged in them."[10] to the comments of Lombroso and Goncourt cited by Mozans who maintained respectively that there may exist an occasional woman of talent, but there can be no genius in a truly womanly woman or there are no women of genius; when they have genius they are men.[11]

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[9] Rossiter, "Women Scientists in America Before 1920," p. 320.

[10] Scientific American, August 1870, Reprinted in Scientific American, September 1970.

[11] H. J. Mozans, Woman in Science. Cambridge, Mass.: The M.I.T. Press, 1974. First published 1913, p. 109. The remarks were made in the 1890's.

SECTION 3

The Medieval Contribution to Scientific Thought and the Status of Women in the Middle Ages

The Medieval Contribution to Scientific Thought and the Status of Women in the Middle Ages

The history of the changing attitudes of different eras toward all the achievements and contributions of the medieval period is varied and complex and lies largely outside the scope of this topic. However, while (almost) everyone honors the Greeks and Romans and their achievements, such has not been the case for those who lived in the succeeding thousand years. Even today, the value of the medieval contribution outside religious philosophy and cathedral building is a subject of debate.

Nevertheless, no longer is the entire medieval era dismissed as the "dark night of the mind" -- an era of cruelty and superstition or romanticized as it was in the nineteenth century because of its code of chivalry and its ideal that everyone had a place in the scheme of things and with that place went rights as well as duties. Another tradition of the nineteenth century, especially in England, when medieval history began to be studied systematically and those dusty scrolls read,was to attribute the origin of the present world to the medieval experience not the the splendid achievements of the Greeks and Romans. To some extent these romanticists and historians went overboard in opposition to the men of the Renaissance and the Enlightenment who detested all things medieval.

The reason a more balanced view prevails today is that it is possible to come as close to a clear view of medieval scientific thinking as it affected medieval civilization and evolved through successive eras into modern scientific thinking as it is of any culture that is studied historically. This is not the case when one attempts to trace the history of classical scientific thinking as it evolved from the Ionian Greeks in the sixth century B.C. to Archimedes in the third century B.C. It is not just a case of the medieval period being nearer to us in time; it is also that enough of the documents survive. As Charles Singer suggested in 1928 when he wrote the preface to his book of essays on aspects of medieval and classical scientific thinking, *From Magic to Science, Essays in the Scientific Twilight*. "The only adequate historical record that we have of the rationalization of thought, affecting an entire civilization, is to be found in the documents which display the passage of the medieval into the modern way of thinking. The history of that process, when it can be written in proper perspective, should provide an absorbing theme."[1] That Singer's suggestion was valid is demonstrated by the increase in the study and evaluation of medieval scientific and technological achievements since Singer wrote. Moreover his comment holds true in another topic that lies within our subject -- their thinking on the position of women. Enough of the record survives, skewed perhaps, because it comes to us via the nineteenth century interpretation of English common law as it pertains to women and the nineteenth century conception of medieval courtly love. Singer's ideal book has yet to be written for either topic nor is it germane to our purpose to write it or even outline it.

Our purpose is to set forth the complexity of medieval thinking on both subjects and to isolate those elements of it that evolved into the framework of our attitudes toward science and the position of women. The two are related as is demonstrated by the fact that scientific thinking is still a man's world and women as a group occupy marginal and tenuous positions within it.

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[1] Charles, Singer, *From Magic to Science, Essays on the Scientific Twilight*, New York: Dover, 1958, p. xix.

Whether intentional or not, most authors dealing with medieval science still tend to treat it as a series of isolated discoveries which "anticipate" the modern era or discuss medieval physical theory from the point of view of its completeness and sophistication or lack thereof and most especially its strangeness and emphasize or de-emphasize its differences from modern theory. Seldom is medieval science or physical theory discussed in terms of the medieval world view and the special conditions that obtained in the Middle Ages. However, two things should be remembered: the direct ancestor of modern scientific theory is that of the Middle Ages for two opposite reasons: 1) in its extreme form, medieval scientific theory was rejected but at the same time, this rejection led to the formulation of scientific theories of the 16th-19th centuries and, 2)elements of medieval science were useful to future scientific techniques and our technology and the achievements of the Industrial Revolution are solidly based on the practical accomplishments of medieval man as they attempted to put nature to their use through mechanization as well as human power.

In a presidential address given before the American Historical Association, San Francisco, December 1973, Lynn White, Jr., a medievalist, had the following commentary to make on what he felt was the principal relationship between medieval and modern science:

> On October 13, 1972, the American federal government established in Washington an Office of Technology Assessment to advise Congress on legislative problems related to new technology and its probable impact. This act reflects an ambivalence toward engineering innovation that has been rare during the last thousand years in Occidental culture of which we are a part. Both pagan and Christian antiquity, of course, had been dubious about technology . . . The Latin Middle Ages, by contrast, developed an almost entirely affirmative view of technological improvement. This new attitude is clearly detectable in the early ninth century, and by 1450, engineering advance had become explicitly connected with virtues: it was integral to the ethos of the west . . . Medieval Europe came to believe that technological progress was part of God's will for man. The result was an increasing thrust of

> invention that has been extrapolated, without interruption or downcurve, into our present society.[2]

Throughout the rest of his address, Professor White speculated on two things: why something that was regarded as a positive good, at least as late as the latter part of the twentieth century had progressed and had now come to be viewed with suspicion and how the Middle Ages would have fared had there been Offices of Technology Assessment then. What was being put forth by Professor White was something that had been suggested earlier; we live in a time of changing values and it is at these times we seek origins, causes, try new things and try to chart our future. The other thing White has suggested that has bearing for our analysis of medieval science is that the solution to a specific problem that would work drew medieval men just as much as erecting structures of scientific theories to explain the world to themselves and these two tendencies remain very must evident down to the present times -- especially in the United States. Though not everyone would agree that the line between our present technology and that of the Middle Ages is as clear as Professor White sees it, nor would everyone accept that the pragmatism of the medieval period was as he suggests; the general thesis that inventions and technology began to come into their own is uncontested.

Basic to an understanding of medieval science are two things -- how medieval people conceived truth and what their "world view" was.

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[2] Lynn White, Jr., "Technology Assessment from the Stance of a Medieval Historian," American Historical Review, Vol. 79, no. 1, February 1974, p. 1. For a fuller explanation of his view of technology in the Middle Ages, see Lynn White, Medieval Technology and Social Change, Oxford, 1962.

Despite what seems to us their distressing lack of concern with exactness in such things as the population of a city or whether a miraculous event really happened, people in the Middle Ages were concerned with truth, but it was a different kind of truth. Truth was not conceived of as factual accuracy. It was conceived of in a more literary way -- personal and didactic. Thus, if something seemed reasonable, "fit" with the point being made, and was based on established authority, then it was the truth.[3]

The best way to illustrate this is the famous instance of Galileo dropping a cannonball and grapeshot from a belltower at Pisa. As legend has it, no one knew before then that there is a uniform rate of acceleration for all falling bodies. One reason for this may be that in the Middle Ages no one cared. Not many do today. But for most people in the Middle Ages, and for some today, it was "reasonable" to assume that a heavy body fell faster than a light one and if it was reasonable, it was "true." It is the contribution of the Scientific Revolution, that what is reasonable might not be considered "true." And two final points -- to the medieval mind it was not necessary, in fact it probably seemed a little strange -- to drop cannon balls off bell towers. More importantly, however, the test of truth was not its abstract absolute purity but reasonableness, consistency with the teachings of authority and didactic reality.[4] This conflicts with one strand of our vision of scientific truth arising out of numerous collections of observable facts but it does not conflict too radically with the other strain in our scientific tradition -- the deductive, theoretical one.

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[3] George Deaux, The Black Death, 1347, New York: Weybright and Talley, 1969, p. 29.

[4] Deaux, Black Death, p. 29.

While scientific philosophical theorizing in the classical world was not completely divorced from religion and superstition, to a great extent it was relatively free of it. But during the Middle Ages, scientific theorizing though based on Greek thought almost completely was once again firmly wedded to theology. And on the practical level, science was once again wedded to magic. The triumph of astrology and alchemy which originated well before the Classical Era in the medieval period give proof of this. Yet, that did not mean that solid achievements were not made. If one looks through the topics discussed in the Table of Contents of Crombie's book (Medieval and Early Modern Science) and notes that they include astronomy, as divorced from astrology, the calendar, medicine, the transmission of science from the Greeks to the Arabs to the Latin West, Hindu mathematics, physics, mathematics, metaphysics, trigonometry, Greek and Arabic optics, geology, chemistry (as opposed to alchemy), practical science in the universities to name a few and not to give the names and accomplishments associated with them[5] is to impress the reader with the fact that while science took no quantum leap during the Middle Ages such as it did from the 17th Century on; when you couple it with the technological insistence on what works that resulted in improvements in everything from plows to windmills, you find the stage set for what has been called "The Scientific Revolution."

In order to place all this in perspective; provide a better framework for assessing medieval achievements; and portray the intellectual milleau in which scientists and especially the few medieval women scientists functioned, we should briefly consider the medieval world view.

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[5] A.C. Crombie, Medieval and Early Modern Science, Harvard University Press, 1953, Vol. I, Table of Contents.

The medieval world view is the underpinning of the medieval contribution to science and medieval conceptions of scientific physical theory. The following is an over-simplification of a topic about which volumes have been written and which exercises a perennial fascination. Nevertheless, it stresses the important points and highlights what is different in how medieval people, in general, viewed the world and how we do.

In the medieval perspective the world was geocentric and the human was the final creation of God. The human was also God's greatest concern and the object of his continuing attention. Both the clergy and laity accepted the cosmos as described by Ptolemy, the Alexandrine astronomer of the second century A.D. The earth was the center of the universe and since it was made for humans, it followed that celestial movements not only affected humans, but, if properly interpreted, could instruct them. Moreover, not only the cosmos but all society, indeed all objects and even concepts were similarly arranged in an orderly and hierarchical structure. These views, derived in the last resort from Platonic and Neo-Platonic sources, and reinforced by elements of Hebrew and Christian though, fitted and supported the actual social structure with its pyramid of clerical ranks and offices and its stratification of social classes. The whole universe was regarded as a great ladder of ascending entities running unbroken from Hell to the infinite and ultimate unity of God, from the lowest of insects to the angels, from the simplest of practical concepts to the most exalted philosophical and theological formulations. In this order, each individual and each concept was both a part of some greater whole and at the same time a microcosm of inferior creation; in either aspect in was integrally involved in the "Great Chain of Being.' And in this series, people held a most critical place: half-way between the angels and the animals, participating in the exalted spiritual nature of the one and the base physical nature of the other.[6] Moreover, in medieval thought the insistence that within this hierarchy all people from the Pope to the peasant have assigned to them a part of God's work on earth and that all stations of life have dignity and rights as well as responsibilities had a most productive future. In this ordered hierarchy woman had her place. However, as is demonstrated at another point in this section, there was debate about her place. Given this rigid placement and unease over the theoretical position of women, independent action by women, in theory and in practice, was most difficult.

The great result of this world view scientifically speaking is that one could argue by analogy. For example, the relations of a wife to her husband could be described in terms of the duties of woman to man. Moreover, all things were interrelated and influences on the human from those things above them in this hierarchy were accepted. Thus, an individual was influenced by the actions of the stars just as much as by the weather. As a result, astrology had all the compulsion of eternal and inescapable truth. And it also seemed "true" that an individual could alter those things below him -- minerals for instance. So alchemy and astrology possessed aspects of branches of sciences just as much as astronomy or chemistry by medieval definition. Moreover, these "sciences" were backed by authority (Ptolemy, the Bible) and even had the virtue of being verifiable by "observation."

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[6] Deaux, Black Death, p. 56-57; Arthur O. Lovejoy, The Great Chain of Being, A Study of the History of an Idea, New York, 1936, especially Chapter 3, p. 67-98; Lovejoy is more concerned with the history of the idea from Greek times to the eighteenth century and its effects on eighteenth century thought and biological practice.

(i.e., they appeared reasonable.) Such a view is radically different from ours which is based on "rationalism" and organized observation. However, care must be taken to remember that this was the way things were supposed to work. In practice, they did not. Medieval people were not really frozen in an unchanging hierarchy of beings. Many medieval people recognized this and struggled to account for events and problems in a more "rational" way. It is well to remember that throughout the Middle Ages there were dissenters from this prevailing world-view. One of the most notable of these was Nicoli (Nicholas) Oresme, Bishop of Lisieux (d. 1382),who warned against astrologers and soothsayers, raised rational objections to their teachings, wrote that a widespread belief in an idea does not mean it is true, and that the senses can be deceived.[7] Even the Church was uneasy about such things as astrology and alchemy and from time to time those who practiced them ran into "trouble."

Because the Middle Ages, especially the latter period was a time of great upheaval and change, dimly perceived and even more dimly understood, many people clung tenaciously to this world-view becuase it gave an explanation of the world that was appealing. However, all the while the notion never died out completely that it was best to find out for onesself and make one's own errors rather than to accept the untested 'truth' of authority.

Some of the hallmarks of medieval thought, apparent in their theorizing about the physical world as well as their theological thinking, were that it was wide-ranging, attempted to be all-inclusive, and that it was passionately concerned with order (though some inconsistencies were never reconciled) and logic and appeal to principle authorities (the Bible, Plato, the neo-Platonists [Ptolemy, Galen and St. Augustine] and Aristotle, as passed on to Medieval people). To set forth the medieval Platonic or Aristotelian physical theories -- defined by Thomas Aquinas in the Thirteenth Centruy -- completely would be out of place in such a survey. However, what is feasible and most appropriate is to isolate those concepts that were different in them and those that were most "productive", either because they were built upon by succeeding scientific thinkers or because they were rejected by succeeding scientists and thus became the starting points of what is called the Scientific Revolution. Additionally, it is hoped that it will become apparent that while scientific development took no "quantum leap" in the Middle Ages, scientific theorizing was being done and science in something like its modern form was being practiced both by men and women.

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[7] Deaux, Black Death, p. 57.

Up until the twelfth century with the reception of classical Greek scientific works, especially those of Aristotle, and also the contributions of the Arabs, no clear-cut physical theory, as we would consider it existed as such. There were great scholars but they were primarily interested in theology, philosophy and logic.

Though God was the ultimate cause of everything to medieval men, those following the Platonic scientific interpretation accepted mathematics as the key to understanding and explaining the physical world and by this they meant more than what we mean -- that mathematics is the language of science. It was also the secondary cause of such things as celestial motion. Because they followed the authority of Plato, geometry reigned with these scientific theorists, even though they worked with algebra. The major flaw of this new-Platonic physical theory is that it could not account for change in things satisfactorily. Because for the Platonists and neo-Platonists ideas were immutable, then every image (the realization of an idea) should be the same, but this is obviously not so. Plato realized this difficulty as did his medieval successors, but they never satisfactorily solved this problem. As a result, those following Platonic theory were left not only being unable to account for change, but also they could not define or work with motion very well. The most they could say was that the primitive elements of water, earth, air and fire originally moved in all directions by chance.[8]

When Aristotelian physical theory (first adopted by Albertus Magnus (1206-1280)[9]) was given its clearest expression by Thomas Aquinas (1225-1274), it was received with great suspicion as being too radical and possibly heretical. But ultimately the Aristotelian/Aquinas view swept the field. Moreover, Aristotle's Physics became the basic book required of all candidates for the masters degree. As a result of the fact that it is the weakest of Aristotle's scientific works, a far from easy book to comprehend and was in many cases poorly taught, just how much scientific theory the average university student learned is questionable.

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[8] Weisheiphl, James A., The Development of Physical Theory in the Middle Ages, New York, 1959. The description of Platonic physical theory is taken from Weisheiphl, p. 12-19, passim. The reflection on the relationship between medieval thought and later periods are the author's. Also, the decision to discuss both Platonic and Aristotelian physical theories at this point rests on the fact that one of the most important aspects of their systems and cosmologies is how they both accelerated and retarded scientific thinking in its purest form in the medieval period.

[9] Albertus Magnus was the teacher of Aquinas; scientifically unlike Aquinas, he was interested in what we would call the experimental as well as the theoretical side of science.

The reason for the popularity of the Aquinas/Aristotle physical theory was that it appeared to explain reality, change and movement more satisfactorily and its interpretation fit well with the medieval world-view and it left intact the Ptolemaic astronomy which fit best with the cosmology of medieval man.

Briefly, basic to this theory is not idea and number but change and motion as they exist in nature. Ideas are abstractions, terms to classify real things. Moreover, every physical thing moved or changed in some way. While observation is essential to determining cause, generalization is the logical and fundamental place to being an explanation. Aquinas did qualify this by insisting, "A science which regards things only in general is not science complete in its ultimate act ... Hence it is evident that science to be complete, must not be content with general knowledge but must proceed to a knowledge of the species."[10]

Though Aquinas/Aristotelian physical theory more or less dominated the field, there were dissenters and the neo-Platonic theory always had its proponents. Both were deductive systems (a contribution still prevalent in our scientific reasoning), both had drawbacks and other variations of these theories were put forth. But neither was totally rejected in the Middle Ages because they fit so well with the medieval world view. However, when the Thomist interpretation of the physical theories of Aristotle became the prevailing one, its defects became more obvious. It did not allow for what we would call true observation and experimentation, and the insistence, despite evidence to the contrary, that it was the right explanation became a positive result in that it too, like theories before and since, was the starting point for a new age of theorists. Its chief virtue, in our eyes, was that it provided a clear method for deductive, rational thinking.

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[10] Weisheiphl, Physical Theory, p. 35.

By way of summation, the medieval world view and the main physical theories that accompanied it have value because they demonstrate that theorizing was an important activity in an age that was technologically gifted but not overly productive of what we would regard as pure scientific achievements. Moreover, except in rare cases, this was not an age in which theory and technology accompanied one another. (In this respect the medieval era was not too dissimilar from other periods already discussed. However, the cleavage was much more distinct in the Middle Ages.) Implicit throughout this discussion of medieval science is the fact that as an institution it was not independent but was, rather, an off-shoot of the religious university system. As a result it never shed its religious overtones.

The result was that medieval people experienced great difficulty in trying to fit an explanation of physican phenomena into a prevailing world view that was non-scientific. (The same may be said of the Classical Era as will be shown.) Unlike the periods from the seventeenth century on, where science and technology became intertwined and achieved independent institutional status with the result that scientific thinking came to dominate the world view, the Middle Ages remained religiously oriented and science, in general, was the handmaiden of religion.

Insight into specific areas could be gained, starting-points for genuine scientific achievements could be laid out, but difficulties lay at every turn and often they were not recognized or if they were, only tortuous explanations could be given.

Yet, the starting point of this discussion was that it was in the medieval period that the road to what we call modern science and technology was begun. And the contention is valid. As has been noted, a basic element of modern science, was securely established. In the second place, the role of mathematics in science, both as a tool of science and as an independent science, was even more firmly defined. Not all of this was due to Aquinas or the neo-Platonists. Much of the mathematical work and theorizing was done late in the Middle Ages and can be considered work on the qualification and quantification of problems in what we call physics (a part of the medieval natural sciences). However, despite the achievements of the Middle Ages, medieval scientists did not set science on the road to independent status. That process, as has been noted, began in the seventeenth century.[11]

As far as individuals concerned with things in the realm of science in the Middle Ages, the biggest single deterrent to outstanding achievement by both men and women was not the prevailing world view or the insistence on orthodoxy by the Church, but rather the fact that almost all persons interested in science, with the exception of physicians and surgeons who were lay people, had to be part of the Church. As a result they had many duties and responsibilities that did not leave them much time for the pursuit of science. Moreover, the world of science was effectively closed to all those who were not in minor orders (of the Church) at a minimum. To say the least, science in the Middle Ages was the province of a select few. And women seldom were among the few.

One example, out of many, will suffice to illustrate the life and difficulties of a medieval scientist. Albert the Great (already mentioned as the first proponent of the Aristotelian scientific theories and the teacher of Thomas Aquinas) collected and categorized one of the most outstanding collections of plants in the Middle Ages, which served as an aid for botanists in later periods, spent at least part of his career as a professor, a Provincial for the Dominican Order in Germany and a traveling preacher throughout various countries in Western Europe. He did not turn to science, in a systematic way, until he was forty. Albert the Great stands in sharp contrast with today's scientists who begin their careers early and have their most productive years usually before they are forty.

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[11] Crombie, A.C., "Quantification in Medieval Physics," Change in Medieval Society, New York: 1964, p. 188-297.

This observation and example of the difficulty of pursuing a career as a full-time scientist in the Middle Ages had implications for the period down to the mid-nineteenth century as well. Science not only was a part-time pursuit but it was also never conceived of as a secular pursuit with its own value, rules and regulations. Only gradually did this view come to prevail. As we have seen, it was not until science emerged as a discipline and as an independent institution as well that it achieved real status and its followers real prestige. Moreover, while it was almost impossible for women of the Middle Ages to pursue science; when science achieved its independence, women occupied only a fringe role in science as we have seen. Not only is this true of the periods already discussed, it is also true of the Classical Era which remains to be examined.

It used to be said that one medieval scientist was a candidate for the title, "the only true scientist of the Middle Ages." The thing that intrigued both sciencists and historians was the speculative nature of his thought. This man was Roger Bacon (1214?-1274). Unlike Albert the Great, he did not follow an active career in the Church but remained in minor orders. In a way, he can be considered a medieval Leonardo da Vinci in that among other ideas, he felt that in the future, men might develop a way to fly and wrote about many ideas and machines that we have today. However, Roger Bacon's life, thought and achievement have not survived the scholarship of modern medieval historians. His speculative thought was indeed out of tune with the theory and practice of his time, but he was not, as is popularly thought, a martyr to religious superstition and like Leonardo did not achieve as much of actual utility as did some of his compatriots.

Though he was imprisoned, it was not, as used to be thought, for science, but because he got caught up in a university faculty quarrel. He did provide a quotation, similar to that of Nicholas Oresme's, which served as a kind of guide for the direction of future scientific action, "There are three ways in which men think they can acquire knowledge of things: authority, reasoning, and experience, only the last is effective and able to bring peace to the intellect."[12]

Medieval science and technology can be considered both an end and a beginning. In scholastic physical theory is found the culmination of the medieval way of thinking about the physical world that fully reflected the world view of that era. Today, science dominates our world view. The body of medieval scientific thought served as a basis, or to use a medieval word, an impetus for new and more profitable ways to analyze both the natural world and the problems it presented. In addition, in the dedication to the positive good of technology and the remarkable record of achievement in that area that medieval people acquired there is a clear step into what we would call the modern world.

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[12] Brinton, Ideas and Men, Englewood Cliffs, 1950, p. 172.

The Position of Women in the Middle Ages

The basic point of the first opening quotations was that the position of women is the test point by which the civilization of a country or of an age may be judged. Such a standard may be challenged but it is useful; and, when coupled with an evaluation of one of our most prestigious endeavors, science, as it existed in the period or country under question, it is also thought-provoking. This is especially true in the case of the Middle Ages. It is our contention that in the case of science, the Middle Ages contributed to the shape of present-day science in two ways -- it provided the basis for further achievement in the area of the natural sciences and in the area of technology both by its inventions and its positive attitude toward technological progress which served as the starting point for the Industrial Revolution. However, the physical theories then dominant and the basic medieval world view are foreign to our present attitude and theories. The case is not the same for a great deal of medieval thought about what we call "the woman question." Nor is it the same in the case of medieval thinking on the question of education for women and the participation of women in intellectual life, especially that part of it we call science. In both these instances, medieval thought, attitudes and practices are the source of our traditional value system that is still pervasive today.

At present, we are still grappling with what is the position of women. We say, or at least many of us do, that it should be one of full equality and that means being allowed and even encouraged to participate in all vocations, including science, on the basis of ability and desire. However, for women to achieve this status has been particularly vexatious because we have a long inheritance of mixed attitudes toward women and their proper role. And this is true of both men and women at all levels of our society.

It is well to keep the remainder of the quotation in mind. The test is a difficult one because what constitutes the position of women is not all that easy to determine. In theory and in law it is one thing; in everyday life it is another. This observation has been amply demonstrated by the material presented on the periods following the medieval and classical. What remains to be done is to show how the ideas and practices with respect to women in society as a whole and in the field of science especially receive their distinctive forms in the Middle Ages.

The question of what was the position of women in the Middle Ages in general and with reference to science is of great interest to us because while Plato and Aristotle's view about the proper role of women in society form the basis for some of our attitudes, they do so because they were incorporated into medieval thinking about the role of women. It is to the Middle Ages that we go for much of nineteenth and twentieth century thought about the role of women both legally and socially. The examination of this topic is complicated by the fact that the role of women was a subject that generated a great deal of thought, much of it contradictory, in the Middle Ages, and at a pragmatic level the position and treatment of medieval women introduced yet another set of factors that influenced us. We encounter the medieval woman scientist at these two levels -- theoretical and practical. To add to the difficulty of trying to assess the position of women in the Middle Ages is the fact that because it was a subject of much debate in the medieval era, it has engendered much debate in later periods because authors have tended to find what they sought -- abject subjection to positions of power and intellectual freedom and responsibility.

It is not possible to examine fully such a rich secondary literature much less the extensive primary literature -- not even that directly related to the topic. For our purposes, because they considered the questions of female achievement and specifically scientific achievement, the views of H.J. Mozans and Eileen Power deserve to be considered. H.J.Mozans was an American who wrote in 1913 under a pseudonym and was not primarily a historian. He wrote what still remains one of the few full-scale historical treatments of the topic that exists and which has received much notice, Woman In Science. Mozans' aim was two-fold. He wanted to demonstrate that women had the capacity for any intellectual endeavor including science if they were given the opportunity and training to exercise that capacity. He also thought that he lived on the verge of a new era and in a country where woman's capacity for science would be fully realized [13] and therefore he wanted both men and women to be aware that women had a heritage of scientific achievement. In general, Mozans viewed the Middle Ages as an equivocal one for women with regard to intellectual pursuits. In only two places, the convents and the universities of Southern Italy, did women have the opportunity to exercise their intellects freely. Though he acknowledged the achievements of aristocratic ladies in such arts as poetry, basically, for Mozans, the medieval period was not a great one for female scientific accomplishment not only because the medieval attitude toward women and their place was equivocal, but also because the medieval attitude toward science was equivocal.[14]

Eileen Power, the author of the opening quotation, was an outstanding English medieval historian of the twenties and thirties. Her interest was social and economic history and one of her concerns was the position of medieval women in general.

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[13] Mozans, H.J., Woman in Science, Cambridge, Mass., 1974, (1st publication in 1913,) p. 101.

[14] Mozans, Woman in Science, p. 53, p. 106-109, p. 144.

Her background influenced her view as much as Mozans' did his. She lived in a country where it was not at all obvious that women were going to achieve what seemed so near to Mozans. Moreover, she worked in a field not noted for its acceptance of women. In addition, she was a trined historian. As a result, her analysis of the role of women in medieval society was much more complex and she found much that was good about the condition of women at that time. However, she was very cautious about the scientific achievement of women in the Middle Ages and she dismissed Mozans' coeducation and Italian universities with their women professors and physicians with the comment that "... Trotula and the famous women doctors of Salerno are rapidly melting away under the cruel searchlight of modern research."[15]

In the Middle Ages, women achieved a kind of negative status on a superficial level in that their proper sphere was the subject of innumerable didactic treatises addressed to them according to Eileen Power. Almost everyone, male and female, had something to say on the subject. Moreover, the characteristics of women, their merits and defects, what they should do and how they should be treated, engendered a whole literature.

The basic medieval theory about women was the creation of two forces, the Church and the Aristocracy. Not only were the Church and the Aristocracy at odds with each other, but each was at odds with itself, and both taught the most contradictory doctrines. All this in a culture that valued order and an assigned place for each person. It can fairly be said that the status of women was the test point of medieval civilization for it threw into sharp relief all of the inconsistencies inherent in the beliefs of the two chief institutions of the day. Thus women found themselves alternately in a pit and on a pedestal.

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[15] Power, "The Position of Women," The Legacy of the Middle Ages, Crump and Jacob, ed., p. 422.

The principal source of this confusion was the Church. Very early in the history of the Church its attitude was Janus-faced. The theories between which the theologians, the Church Fathers, the priests and monks and other ecclesiastical writers vacillated can be summed up neatly in one question. "Was she Eve, the wife of Adam, or was she Mary, the mother of Christ?"[16] The Church never evolved a definite answer. Had the Church been more consistent, the condition of women might have been much altered.

The view of woman as an instrument of the Devil, a thing at once inferior and evil, was the creation of the early period of the Church. It was an idea found neither in Roman or barbarian thinking. The conception of woman as the supreme temptress, the most dangerous of all obstacles in the way of salvation came into being along with the ascetic ideal and image of the monastery as a refuge from the troubles and turmoils of the world. In practice, it had little influence on men's daily lives; they continued marrying and invoking the blessing of the Church upon their unions. But the monastic view slowly permeated society. The clergy, for many centuries, the only educated and hence the only articulate section of the community, preached the ascetic ideal, and it is not surprising that the fundamental theory about women should have been a theory of their essential inferiority.

Only a few took the theory to the extremes, nor did most accept the idea of the evil nature of women very seriously. What they did accept was the subjection of women. The ideal of marriage, in the majority of medieval didactic works addressed to women, is founded upon this idea and assumes the most implicit obedience on the part of the wife accompanied by the view of her as a possession. Nowhere is this more clearly marked than in the comments on feminine honor found in a thirteenth century treatise. "Women", comments the author, "have a great advantage in one thing: they can easily preserve their honor if they wish to be held virtuous, by one thing only ... And for a women, if she be a worthy woman of her body, all her other faults are covered and she can go with a high head wheresoever she will..."[17]

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[16] Power, "Position of Women," p. 402.

On the other hand, the Church also developed the counter-doctrine of the superiority of women, with no apparent sense of incongruity. In this they were assisted by the Aristocracy for the doctrine of the superiority of women depended not only the adoration of the Virgin in heaven but also of the lady on earth. The latter was based on the ideal of chivalry which was handed down to the modern world. The cult of the Virgin, widespread at all levels of society, and the cult of chivalry of the Aristocracy, products of the later Middle Ages, grew together and reacted upon on another. By the eleventh century the Virgin was supreme and supreme she remained until the end of the Middle Ages. The cult of the lady was the mundane counterpart of the cult of the Virgin. In chivalry the romantic worship of a woman was as necessary a quality of the perfect knight as was the worship of God. This is clearly expressed in a French ballade of the fourteenth century, "In heaven a god, on earth a goddess."[18]

It is obvious that a theory which regarded the worship of a lady as next to that of God and conceived of her as the mainspring of brave deeds must have done something to offset the dogma of subjection. The process of putting a woman on a pedestal had begun and while that was not entirely satisfactory either as it worked out, at least it was preferable to being consigned to a bottomless pit as the Fathers of the Church had been inclined to do. A caveat must be made. The doctrines of asceticism and chivalry were the products of a tiny portion of medieval society and while the ideals were widespread, in practise most people of the Middle Ages, even within the Church and the Aristocracy, did not live their lives by such extreme ideals. Power contends that it is probable that the ideas of chivalry had more influence upon later ages than it had upon contemporaries and as a legacy it has certainly affected the position of women in modern times. As a result she feels it was one of the most powerful ideas evolved by the Middle Ages and it was, substantially, an original idea.[19]

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[17] Power, "Position of Women," p. 404.

[18] Power, "Position of Women," p. 405.

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However, theories are not the only guide to the status of women. Power discusses in detail what the practices were with regard to medieval women of all classes, both married and single. This is not the place to present a long description of a complex culture with many variations in practice that changed over a long period of time and from place to place. Then too as Power comments, "... we hardly ever hear what women thought about themselves. All the books, as Chaucer's Wife of Bath complained, were written by men."[20] Works written by women with commentary on their condition were rare, indeed apart from mystical literature and literary material originating in convents; there were not many works by women at all until the later Middle Ages.

Some generalizations and some ramifications about the state of women in practice can be made. The normal state of women was marriage. At all levels of society, marriage was a property transaction as well as a religious sacrament and a personal relationship. Basic to all three aspects (property transaction, religious sacrament, personal relationship) was the dogma of the subjection of women which became embedded in the common laws and left to future generations a legacy which was long in dying. From this is followed that woman was not legally 'a full and lawful person,' that she had no lot or share, then or until the twentieth century, in what may be called public as distinct from private rights and duties, and that the higher grades of education were closed to her. On the other hand, she had a full share in the private rights and duties arising out of the possession of land (including administering her inheritance or her children's inheritance in the absence of a husband). Furthermore, among the middle and lower classes, women played a considerable role in trade and industry and as such also had rights at law.[21] Because marriage was conceived of as permanent, because it was a legal transaction, and because marriages took place well before what we would conceive of as a marriageable age, romantic love played no part in marriage. That occurred outside marriage and among the chivalrous knights and ladies. In good marriages, affection and camaraderie grew, but 'marrying for love' was a thing almost unheard of.

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[19] Power, "Position of Women," p. 406-407.

[20] Power, "Position of Women," p. 408.

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The education of the average laywoman compared very favorably with that of her husband, in part because the Church taught that her soul was equal to that of any other person's in the eyes of God and she needed to know enough to save it, and in part because her economic and legal role within the marriage demanded the skills of reading and writing as well. The literacy of laypeople became more widespread in the later centuries of the medieval period and there was a tradition of literary accomplishment among laywomen of the aristocracy.[22]

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[21] Power, "Position of Women," p. 404.

Among the lower class and to an extent in the middle class there was a place for the single woman or the spinster. It was in the world of work. She played an important role in agriculture, in certain trades and industries and as domestic help in the households of the upper middle class and the aristocracy. Although there was little place in the society of the upper classes for the independent unmarried woman, she found an honorable occupation for herself in monasticism. Within the convents, women were educated and the result was a great tradition of mystical writing, a tradition of charitable works such as caring for the poor and sick and in the case of the abbseses a proud reputation for executive and organizational action. They showed themselves just as skillful, if not more so, than the great queens in protecting their lands and estates and all the rights that went with them, both at law and on occasion at arms. One of the most interesting essays on this subject, "The Lady Abbess," was written in 1910 by Emily James Putnam, distinguished classicist and first Dean of Barnard College. Putnam writes:

> "No institution in Europe has ever won for the lady the freedom of development that she enjoyed in the convent in the early days. The modern college for women only feebly reproduces it, since the college for women has arisen at time when colleges in general are under a cloud. The lady-abbess on the other hand was a part of the two great social forces of her time, feudalism and the church. Great spiritual rewards and great worldly prizes were alike within her grasp... In the cloister of the great days, as on a small scale in colleges for women today, women were judged by each other, for sterling qualities of head and hear and character."[23]

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[22] Power, "Position of Women," p. 408-409.

[23] Putnam, E.J., The Lady, Chicago, 1969,(first publication 1910,) p. 71.

In her presentation of the role of the abbess and the convent in the great days of medieval monasticism Putnam portrays, as does Power in her generalized description of the position of medieval women, the pragmatism that also played such a role in medieval relationships between women as well as between men and between men and women. Moreover, Putnam offers us in her last sentence a succinct estimate of one part of the medieval attitude toward religion for nowhere does she comment on the religious qualities by which the abbess is judged.

Finally, in comparison with the home of today, for every class of married medieval women, married life gave her as great a deal of opportunity for independent action as that which her religious sister experienced, since the home of the Middle Ages was a very wide sphere; social and economic conditions demanded that a wife should always be ready to perform her husband's duties as well as her own, and that a large range of activities should be carried on inside the home which are performed outside the home today. It is well to remember that until late in the Middle Ages, in all ways, but especially economically, life was marginal and survival was a basic question. Every person and every institution had an economic role to perform. Since life was geared to survival, the work of every person was needed to survive and in such a situation equality often arises in practice if not in theory.

Before examining the intellectual and scientific contributions of women in the Middle Ages it seems appropriate to summarize by quoting from Power and from an equally respected medievalist who dissents from her assessment.

Power concludes by saying:

> "Finally, while the Middle Ages inherited the doctrine of subjection, to some degree at least, from the past, it evolved for itself and handed down to the modern world a conception of chivalry which has had its share in the inspiration of poets, the softening of manners and the advance of civilization. Taking the rough with the smooth

> and balancing theory against practice, the medieval woman played an active and dignified part in the society of her age."[24]

While the mainstream of later interpretations of the position of women in the Middle Ages follow Mozans and Power, there are dissenting evaluations. One dissent comes from some of the feminist literature both of the nineteenth and twentieth century. This body of opinion has been discussed in some detail. For the moment, the major thesis of such authors is that the negative impact of the theoretical teaching of subjection, especially as embodied in the common law, and the long-range negative result of "putting women on a pedestal" outweighs the tradition of practical equality which, in any event, was dying out by the end of the Middle Ages.

Feminists are not alone in maintaining this position. Medievalists from two schools, those whose special concern is the later Middle Ages and those who are Marxists, disagree with the interpretation of the mainstream as exemplified by Power and others. They can point to the fate of Joan of Arc, the woman most likely to be remembered of all medieval women. Though she donned armor and helped galvanize the French armies into saving her vacillating king's heritage for him and in so doing became a popular heroine and ultimately a symbol of national pride and a saint, her immediate fate was not so pleasant. She was burned at the stake as a heretic in a purely political and expedient action.

Friedrich Heer, the noted German medievalist, whose book, The Medieval World, contains the best short statement of this view, exemplifies the dissenting view of a non-marxist medievalist position. Writing in 1961 and concerned with the period from 1100 to 1400 he equates the position of women in the later Middle Ages with that of the Jews though he concedes there was much less uniformity of thought about women and active persecution did not become the lot of most women. However, he too makes general conclusions. "By the close of the Middle Ages one social axiom had become firmly established and was long to remain in force: 'Woman's voice is not to be heard in public.'"[25] His more extended conclusion is that starting with Aquinas in the thirteenth centruy woman was deemed an object useful, but not necessary for man and essential only for conception and bearing children. Moreover, there is an increase in literature portraying women with hatred and distrust and as a perilous object. He attributes this literature to the "inner schizophrenia of the waning Middle Ages." Finally, he summarizes by saying:

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[24] Power, "Position of Women," p. 433.

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> "The women who grew up in the courtly civilization of the twelfth century had learned to 'sing and say', to use their mind and their imagination, to conduct their lives and loves on a highly-civilized plane. In the later Middle Ages there were a few ecstatic figures, burning with a prophetic flame, who stand sharply against the undifferentiated mass of oppressed women forced to accept life and men and misery as they found them ... The Middle Ages had conspicuously failed to solve the problem of woman's place in society; it was left as a heavy mortgage on the future."[26]

As was noted earlier, Heer's interpretation is the one generally favored by historians who either see the entire Middle Ages as a period of unrelieved gloom with little or no freedom for most people and no achievement or those who concentrate on the late medieval period and see it as dying civilization rather than a culture in transition. As noted earlier, this interpretation is also favored by Marxist historians because of their interpretations of the role of the Church, feudalism and the bourgeoisie. These schools of thought see the same evidence from different perspective but generally agree on their negative evaluation.

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[25] Heer, Friedrich, The Medieval World, New York, 1962, p. 317.

[26] Heer, Medieval World, p. 323.

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The main purpose in setting forth in detail the differing interpretations about the status of women in the Middle Ages is because it neatly highlights one of the lessons history does teach and reinforces two earlier assumptions about the literature on the period. What is learned from the past depends upon, to a great extent what one wants to learn. "True objectivity," that goal of scientists, is extremely hard when analyzing a subject as complex as the human past. The difficulty is compounded when there is more evidence in written form left to be analyzed in a manner that will present the beliefs and attitudes of the period about a topic as value-laden as the role of women in society and will set forth those values adopted by succeeding generations. Thus, as has been maintained, the Middle Ages becomes the last period in which it is barely possible to assess the role of pure science or technology of women in relation to their position within society and with science because as science plays an ever larger role within Western culture and the status of women becomes a topic of ever-increasing importance, the "record" cannot be read with any certainty.

Women in Science in the Middle Ages

Though science and scientific achievement took place in the Middle Ages, it should be kept in mind that with the exception of medicine, science as a branch of religion and philosophy was not practiced or theorized about by lay people. Science was the province of the Church and of the universities administered by the Church. The same was no less true for women than for men. Women, who were barred from the universities,were educated and followed intellectual pursuits within convents. The exception was medicine; it was practiced both by laymen and laywomen. Additionally, it should be remembered that it was not until late in the medieval period that laywomen and laymen had access to any great extent to the world of learning.

The main contribution of medieval women both within the convent and without to learning in any field was in the field of literature and letters. And even there, as was noted earlier, the Wife of Bath observed that most of the books were written by men. The love letters of Heloise who gave up her marriage and retired to become an abbess of a convent, the chivalric poems of such women as Countess Beatrice de Die and Marie de France and other less skillful, and the writings of the great women mystics are genuine contributions to literature. In the later Middle Ages, the letters of women not only of the aristocracy but also of the bourgeoisie such as the Paston letters have literary merit and give us access to the opinions of women and insight into the lives they led. In this they are not unlike their successors. As we have seen, literature constituted a major area of female artistic and intellectual expression.

The contribution of one laywoman, Christine de Pisan, Countess and poetess, is of importance, however, she was the first woman professional, if those who practiced medicine are not considered, for she earned her living and supported her children by her pen, and she may be the first feminist. Certainly she is the first to write for her sex and lead a party of revolt against the prevalent abuse of women. Writing at the end of the fourteenth century, skilled in all the courtly convention, there is idealism and reality in her attack on the conventions of the *Roman de la Rose* and in her books about education and household and estate management which she wrote for the use of women.[27] If the evidence of Mozans can be considered on the point, and at present no contradiction is known, Christine de Pisan was also concerned about the role of science in the education of women for in her book, *La Cité des Dames*, she writes about the utility of teaching science to girls:

> "I say to thee again, and doubt never to the contrary, that if it were the custom to put the little maiden to school, and they were made to learn the science as they do the men-children, that they should learn as perfectly, and they should be well entered into the subtleties of all the arts and sciences as men be. An peradventure there should be more of them, for I have teached here often that by now much women have the body more soft than the men have, and less able to do divers things, by so much more they have the understanding more sharp there as they apply it."[28]

Altogether, Christine de Pisan was unusual for her age or any age but her achievements lie outside the realm of science. And, if you exclude the practice of medicine, and there the record is mixed, most of the women who expressed some scientific interest were found in the convents and only one case, Hildegard of Bingen, can be documented fully. There exists much about medieval women scientists that is legend and conjecture. Mozans includes the women of these legends in his book, but his contemporaries, like Charles Singer (already mentioned) and other historians of science have cast doubt on the existence of the others.

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[27] Power, "Position of Women," p. 409.

[28] Mozans, *Woman in Science*, p. 134-135. He follows a sixteenth century English text.

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Hildegard (1098-1197), who in many respects was just as remarkable as Christine de Pisan, was abbess of a Benedictine convent near the then important German town of Bingen and has been called 'the marvel of the twelfth century.' She was renowned for attainments in a varied set of disciplines, her voluminous correspondence and for her sanctity, though she was never canonized. Though the corpus of her works is large, there is no satisfactory biography of her and Mozans' treatment of her is not entirely reliable because he bases his judgment of her, in part, on works that she did not write. The best account of her work is that written by Charles Singer in 1913 and first published in 1917, entitled "The Visions of Hildegard of Bingen." When he writes about the essay on Hildegard in 1928, it is the one of which he is most proud. He started it from the point of view of a pathologist interested in the role of migraine attacks in mystical visions. This led him to an interest in Hildegard's visions which altered his career, for he became a historian of science. When evaluating the role of Hildegard in medieval science in his Preface, he states:

> "In the scheme of this book Hildegard is of importance as representing an early attempt at something like a coherent philosophy, intended to cover the appearances of the material universe. As such her work is, in fact, Science, and with her we have left the Dark Ages and the Dawn has begun. [If we follow Singer, the first modern scientist then becomes a woman, not a man!] In placing this view before the reader we would ask him not to be deterred by what is, for us, the extremely bizarre manner of presentment of her views. She is feeling her way to a rational explanation of her world, and the fact that her solution is not our solution and that she is grotesquely wrong on matters of fact, should not blind us to her intellectual merits. The

same criticisms could, after all, be made of Aristotle or of any other early thinker."[29]

Singer may overstate the case for Hildegard being among the first to develop a coherent explanation of the appearances of the natural world because what Singer sees as the basis for her scientific thought is what we have called the medieval world view shared by most persons throughout that era. For example, she accepted the concentric structure theory of the way the universe was organized (a commonplace of medieval science) though for her its outer spheres were egg-shaped or almost elliptical, not circular. Yet, the earth is circular; but its surrounding fields of what we would call electricity and magnetism were elliptical. Her view of terrestrial geography is not clearly set forth but she does talk about inversions of seasons and climates in the opposite hemispheres. She really subscribes to the view widespread throughout the Middle Ages (found in Dante) that the southern hemisphere is uninhabitable since it is either beneath the ocean or the mouth of a dragon. She also espouses the idea that the four basic elements, earth, air, fire and water, have been mixed here on earth since the Fall of Man but they appear in their pure state in the celestial spheres which surround earth. Each element has a wind associated with it and these winds change earthly conditions such as the weather. Each of the spheres influences the earth in other ways. This view of the universe has its original features, but it is similar to the one which can be traced back through the early Middle Ages to the De Rerum Natura of Isidore of Seville to the neo-platonic-Christianized view presented in the early Christian period. As we have noted, this interpretation of the universe was later partially supplanted by the Aristotelian/Thomistic view of the later Middle Ages.[30]

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[29] Singer, "Autobiographical Note," p. vii-x; (Apparently "The Visions of Hildegard of Bingen" was a best seller for its day.) p. 199-239, for the essay proper and evaluation of the scientific role of Hildegard; Preface, p. xxvi. The Preface and Autobiographical Note were written in 1928. Since "Hildegard" was Singer's first essay in the field of history of science, she apparently exercised a life-long interest for him.

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Throughout her long life, Hildegard refined her view of the universe, repeatedly, until she presented a view that accounted for everything, both in macrocosm and in microcosm and encompassed not only her theological beliefs, but her knowledge of physiology and what we would call psychology. Her system, or variations of it became a cosmic theory which dominated not only the Middle Ages but the Renaissance and even held appeal for Harvey, Boyle and Leibnitz, what is not known is whether she derived these ideas from reading and conversation, internalized them, and reproduced them as visions, or arrived at them independently. There is rather more evidence that many of Hildegard's ideas were unique to her.

Though she had access to some scientific and a few anotomical and physiological sources, the main source for this view of the universe is her visions.[31] In evaluating the visions, which Singer accepts as authentic and having a neurological basis, it is well to remember that many of her contemporaries, some of whom she was in contact with, had visions along these lines though they were not as systematized as those of Hildegard. They were one of the modes of experience in the Middle Ages. It is her systematization and her attempt at a complete and coherent scientific philosophy that makes Hildegard original.[32]

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[30] Singer, "Autobiographical Note," p. 205-216, passim.

[31] Singer, "Autobiographical Note," p. 223-232, passim and p. 234-239, passim.

Though the practice of medicine is not treated or defined as a science in the remainder of this paper, it deserves some consideration in analyzing science and the role of women in science in the Middle Ages. Throughout the Middle Ages, everyone, but especially women of all classes within and without the convents, were expected to be versed in some of the aspects of the medical arts, especially treatment of common ailments and the art of the midwife. Treatises were written for women to use, usually by men, for emergency treatment and treatments related to obstetrics and gynecology because they were the province of women. At the same time, by the middle of the medieval period, what we would call medical schools had been established at the universities throughout western Europe. The oldest of these was at Salerno in Italy where classical teaching had never entirely disappeared. In a trend that has been repeated up to the present time, the products of these schools, male physicians, sought to regularize their discipline and professionalize themselves. [Surgery was the province of the barber until very late in the medieval period.] In doing so, they sought the assistance of the authorities and set up licensing procedures, based on degrees held, not on the amount of practical experience. The net effect of this was to freeze women out of a role in which they had been accepted. Yet, it was a long time before the popularity of the midwife waned despite the opposition and persecution of the authorities at the urging of university-trained male physicians. However, this can be seen as one of the first attempts at professionalization and the resultant effect of pushing women into a marginal status. The midwife exists in European countries in modern form but in the U.S., where the medical profession is most professionalized, the midwife has a precarious role.

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[32] Singer, "Autobiographical Note," p. 239.

Moreover, given the conditions of the times women often had to practice medicine -- there were no physicians available. This was especially true among the poor and in the country. It was in the cities and in the later period that the conflict became intense and the battle to set standards that had the net result of excluding women took place.

We have a genuine example of a woman who functioned as a physician in Paris. (Both Power and Mozans agree on her existence and cite the documents relevant to her court case.) By 1220, there was an edict in Paris that no one could practice medicine unless they belonged to the Faculty of Medicine at the University of Paris and only unmarried men could belong to the faculty. In 1322, Jacoba Felicie, who was well-born and about thirty at the time, fell afoul of this edict and was prosecuted by the Faculty. This was not her first offense. She defended herself ably by presenting an impressive array of healed persons of middle-class origins, both men and women, who had given up on licensed doctors. But because she lacked the license and because she had a previous skirmish with the Faculty, she was fined heavily. She probably went on practicing and doubtless had a wide practice.[33] There is good reason to believe there were more like her. But, finally, they were driven out of existence. Jacoba illustrates the difficulties inherent in a situation where the basic problem was the lack of an all-round knowledge of the causes of something (in this case how the human body functioned and origins of diseases). When this is the case, schooling will not help but rough and ready experience and a common-sense approach may succeed. This knowledge is still being acquired and the practice of medicine is still becoming an exact science. But very early, because they professionalized themselves,

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[33] Power, "Position of Women," p. 422; Mozans, Woman in Science, p. 288.

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(that is they set up a system for obtaining what knowledge there was and a means of excluding those who had not been through the system) men became physicians. In this case, women were excluded from the legitimate practice of medicine. The process was repeated in the nineteenth century in the United States and women today still have a difficult time becoming physicians.

So we close the examination of the role of women in the sciences in the medieval period with a foreshadowing of what was to happen to women in practice of sciences throughout the Scientific Revolution and until the mid-nineteenth century when the trend first began to be reversed. As science expanded and became more formalized, knowledge degrees and sometimes licenses were needed to pursue it. Women were excluded from the world of formal learning and the practice of the science. They made genuine and significant contributions but they were recognized only reluctantly because they had not undergone the process necessary to be a professional. Today, in theory, if one has the ability and the funds, one may acquire this knowledge and the necessary degrees to practice as a professional, regardless of whether one is male or female. However, as is demonstrated in the section on the participation of women in science today, the status of women in scientific professions, though real and significant, is still marginal. Other factors are at work and whether they will operate in the future are the subjects of other sections of our report.

SECTION 4

Science, Women and Society in Antiquity

Science, Women and Society in Antiquity

Unlike the medieval period the age that comprised the hegemony of first Classical Greek civilization and then the dominance of the Hellenistic-Roman view of the world and their relationship to each other does not provide us with one vision (or two) of the role of women in society, the institution of science in society or the role of women in science. Rather, there are many conflicting ideas put forth on all these topics and, in some measure, most of them play a role in our present attitudes and practices toward these elements in our own civilization. This is not to say that the Medieval period was not complex and full of contradictions in its attitudes, but instead to point out that in examining the period that is conceded to be the ancestor of so much of what makes us part of the Western Eurpean tradition much that is interesting and important must, of necessity,be omitted.

A digression is needed here because it must be kept in mind that historical writing on whatever topic or period not only depends on what succeeding persons (historians and others) have written about who did what in the period under question, but also, much more importantly, upon the "record", or what portion of the "record" is available to us. By the "record" is meant what remains of what was written, especially by those who lived at that time about themselves, what they thought and what they thought they achieved. For the Classical, Hellenistic and Roman eras such evidence is fragmentary and scarce. So much has been written about this period that just how little of the "record" has actually survived is often forgotten.

Science, which for purposes of understanding the attitudes of the Greeks and Romans toward it, can be defined as a branch of organized thinking (or philosophy) dealing with the natural phenomena that surround us, began soon after the birth of civilization, which of course antedated the Greeks and Romans; however, the attempt to subdue nature stretches back much farther. This commonplace phrase found in endless Western Civilization textbooks illustrates neatly the problem inherent in trying to pinpoint the precise origin of a particular human activity. A philisophical treatise is not intended. What is meant by the opening statements of this, the last portion of our historical endeavor, is to emphasize that a body of organized thought and observation about a topic is a handmaiden of what is called civilization and also does not usually put in an appearance without the beginnings of civilization. At the same time, what is today called technology has an even more ancient origin. It begins whenever people attempt to mold nature to their needs by means other than brute strength.

Since science is so old it is interesting to note and serve as a commentary on the changing status of science that the word itself is not very old. It was first used by Whelwell in his Philosophy of the Inductive Sciences in 1840. On the other hand, the word engineer, coming from the notion of saving labor by ingenuity and the related word genius have had their present meaning since they were used by the Christian theologian, Tertullian, in the third century A.D.[1] The science of the ancient world differs from our conception in that it was a blend of three elements of their attitude toward nature -- empirical practice, magic and/or religion and rational thinking. Slowly, reason and observation came to prevail but the triumph of empiricism was not complete until the nineteenth century.[2]

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[1] Bernal, J.D., Science in History, London, 1954, p. 7; Barzun, Jacques, Science: The Glorious Entertainment, New York, 1964, p. 31.

The distinctive contribution of the Greeks was to put observation and rational thinking on a firm basis and their conception that the universe is a rational system working by discoverable laws. Greek thinkers and scientists made no clear-cut distinction between science and philosophy as we do. Much of their knowledge of the natural world was derived from earlier civilizations. However, the Greek definition of science as a process whereby the scientists observed nature and made rational deductions based on these observations, even though its influence waxed and waned through succeeding eras, is an important element in our present definition of science. The critical part of this definition is the notion of rational deductive reasoning. Though the Greek were great accumulators and observers, their thinking in the scientific area was characterized by this emphasis of starting with a principle or idea and deducing the consequences that come from it. Though emphasized from time to time as an element of science, the other great branch of scientific reasoning, the inductive approach, was not assured of its proper role in science until the seventeenth century. The other contribution that the Greeks made to our definition of science was to place mathematics within the scope of science. This development was also based on the Greek attitude that science was an outgrowth of philosophy. The Greeks regarded higher and organized mathematics as a branch of logic. The net result of these developments in terms of our present conceptions of science and engineering was to provide the basis for a philosophical understanding of the world and a language, mathematics, by which observations and discoveries about the natural world could be presented and amplified.[3]

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[2] Hall, A.R., The Scientific Revolution, 1500-1800, The Formation of the Modern Scientific Method, Longman, Green and Co., 1954, p. xiii.

There were many different and significant philosophical systems and ideas in the field of science in this period. Too many, in fact, to do more than state that they existed and emphasize their importance in the eras that followed as has been demonstrated. The names of Plato and Aristotle occur most readily, but since their ideas and contributions have been discussed elsewhere, only one point must be added. Plato and Aristotle represent the culmination of two strands of scientific thought in Antiquity but there were other approaches that were at various times just as important.

One scientist of antiquity must be commented upon before turning to our other major topic -- the Classical view of the role of women. Archimedes (ca. 287-212 B.C.) was the pre-eminent mathematician, engineer and physicist of antiquity, and perhaps the most complex and original of the Greek minds in the field of science and engineering. In the world of practical and abstract thinking his contributions were at one and the same time both of immediate and long-range impact. His contributions to accumulated knowledge, the basis of science, are undisputed. While it was not until the translations of his work fell into the hands of Galileo that his true originality began to have real impact, Archimedes was the first scientist to fulfill both ancient and modern definitions of a scientist. Had his work been available to the Middle Ages it would have been appropriated by them. While he was said to have been very much in the tradition of Greek philosophy in his disdain for the practical application of ideas, he is also supposed to have said "Give me a lever and I will move the world." While he was a brilliant inventor, it is in the field of mathematics and physics that his contributions were most influential. Moreover, he anticipated the modern scientific method by listing his ideas, though he discarded these when writing up the final proofs. He was a true Greek in that he regarded his inventions as beneath the dignity of pure science or philosophy. His ideas on specific gravity hydrostatics, though long neglected, remain intact today. In the field of mathematics, his contributions were many and original but of most importance was his use of the method of exhaustion, originated earlier, which in his hands became equivalent to integration as used in calculus. Living at the end of an era of scientific achievement, it is fitting that his death came at the hands of the Romans, engineers par excellence, but only mildly concerned with abstract scientific thought. While the Romans were capturing his city of Syracuse, Archimedes remained busily engaged in working on his mathematics and was killed by a soldier who did not understand what he was doing despite specific orders that Archimedes be spared. In his person, he epitomized the full range of Greek achievement in science as well as its limitations because it could not rid itself of its disdain for the practical world.[4] Thus, he is worth considering for he also epitomizes the tension throughout history and into our modern era between the "pure" and the "applied" which has never really been resolved but may now be considered academic because of their present closely woven interdependence.

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[3] Though famous for their art, architecture and speculation about topics in what we would call scientific areas, the Greeks of the Golden Age were not technologically oriented. Their definition of science, as a branch of rational thought and their development of mathematics, a language for science, constitute their main gifts to us. Thus, the contributions in the areas of applied science and technology were developed in the Hellenistic and Roman ages of antiquity.

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[4] Brinton, Ideas and Men, p. 86-88, passim; Bernal, Science in History, p. 159; Brownowski, J., The Ascent of Man, Boston, 1973, p. 200.

With some exceptions, the Romans preserved but did not add to the Greek and Hellenistic contributions to what we would call pure science. They respected the achievements of the Greeks, especially in literature and rhetoric, and taught Greek works in their schools, but generally they did not improve upon them. Though they were great builders they seemed uninterested in advancing speculative scientific thought. Traditionally, the Romans were accorded the position of adapters from everyone,especially the Greeks. Even here, however, their contributions were limited to whatever could be utilized for warfare and administering a far-flung empire.

The Position of Women in Greek and Roman Thought, Society and Science

When considering the role of women in Greece and Rome, Eileen Power's contention that the status of women is the test-point of a civilization is particularly appropriate. In spirit however closely they were related, two more disparate societies with regard to the role of women than the Greek and Roman cannot be imagined.

The position of women in science in Greece is a reflection of the position of women in Greece generally. Officially, women played no part in the recorded public life of Athens and though this was generally true throughout the Greek city-states, women had more freedom and status in backward and militaristic Sparta, of all places. When the literature, art and religion of the Greeks is examined, women are present everywhere. Heroines, goddesses and female prophets abound. Every aspect of the female personality is explored. On the one hand, it is deified, celebrated and admired; on the other, it is deplored, satirized and feared. Ambivalence toward women and things female has never been more clearly and elegantly expressed. The contrast has never been greater -- the richness of the feminine role in the world of the mind and the utter nullity of the Athenian woman of the upper classes whose whole world was her home and whose life stopped at the door.

Through the literature of the late fifth century B.C. and early fourth century there are hints that this state of affairs might have been under reform. Protests against the exclusion of women from public life appeared in plays; women were admitted to some of the philosophic schools -- however, little came of these efforts when the life of the Greek city-states began to disintegrate under the pressure of internal and external wars.[5]

In the philosophy of the Greeks of the classical and post-classical world, two antithetical ideas about women receive their fullest expression. Both became part of our heritage. The first as expressed in Athenian life -- woman's place is in the home -- was not new with the Greeks, but as they did with everything else, they systematized it and developed it philosophically. It was most clearly set forth by Aristotle.

The other point of view, which was systematized by Plato, grew out of his concern over the waste of good material for the state under the then current situation. He held that the difference between the sexes was not of kind but of degree; women were weaker than men, but not less able to share their civic functions, including that of philosophic sovereignty.[6] In the fifth book of The Republic, Plato proposed abolishing the private household and forming all citizens of both sexes into a single state-family. Marriage, the rearing and nurture of children, were all to be controlled by the state. The reasons for this were to insure the quality of the ruling class and the abolition of the idea of private property. According to Plato, this would lead to the ideal state.[7]

Much of what Plato said appeared in feminist literature in late nineteenth century United States in various forms. Whether or not the feminists were aware that their idea originated in the thought of Plato is debatable. One feminist in particular, Charlotte Gilman-Perkins, writing at the close of the nineteenth century, developed similar ideas. Her theories originated in her belief that until women were freed economically and participated in the world of work on the same basis as men they would not achieve real equality or equal status with men.[8] Today, the argument that unless women are used in such areas of vital national interest as the sciences, we will be wasting a valuable resource is once again popular.

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[5] de Burgh, W.G., The Legacy of the Ancient World, London, 1923, (reprinted Penguin, 1965,) p. 184.

[6] de Burgh, Legacy of the Ancient World, p. 184, (emphasis added.)

[7] de Burgh, Legacy of the Ancient World, p. 185.

However, it must be emphasized that Plato's philosophy was not widespread. Though his views on the role of women appear, now and again, especially in the Utopian literature of later periods, his disdain for equality and his preference for an intellectual aristocracy have militated against full acceptance of what he propounded.

On the other hand, the ideas of his pupil and successor, Aristotle, found widespread acceptance. Radical reformers and respected philosophers notwithstanding, Aristotle set the prevailing view in a philosophical framework. He justified his approach by appealing to common sense. Women differed from men in kind; they were defective -- though not entirely lacking -- in intellectual and moral capacity; therefore, while debarred from full citizenship, they must be ruled by men constitutionally, not despotically like slaves.[9] Women were barely tolerated under Aristotle's system. Therefore, they were to receive education consonant with their subordinate position. They were not treated as independent persons.

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[8] Chafe, William H., The American Woman, Her Changing Social, Economic and Political Roles, 1920-1970, p. 7-9, passim. Chafe's introductory essay on the nineteenth century feminist movement as it moved toward the twentieth century and settled on suffrage as the way to achieve the movement's desired goals is most concise and interesting.

[9] de Burgh, Legacy of the Ancient World, p. 185, (emphasis added.)

Aristotle's ideas on women and science are pertinent in this historical overview. He felt that women lacked scientific intelligence and the quality of mind that carries authority; in our terms, women were not capable of abstract thinking.[10] The importance of Aristotle lies not only in the fact that he exemplified the dominant thinking of the classical period, but also in the fact that he sounds so familiar. His thought was intertwined with those who succeeded him in later periods. When an authority was needed, Aristotle was cited. In this way, Aristotelian and Greek misogyny became part of the basis of medieval, renaissance and nineteenth century thought about the nature, capabilities and functions of women and so became a legacy for us.

Two points remain to be discussed -- were there any women scientists in the classical era, and if so, how were they treated and what were their contributions, and what were the unique Roman contributions to thinking about science and the role of women.

The following must be kept in mind in considering and evaluating the achievements of male and female scientists in different periods. As Lynn M. Osen writes in the introduction to her book, Women in Mathematics:

> It is tiresome and counterproductive to argue about the relative merits of male and female mathematicians (scientists), for we have not precise method of quantifying or comparing their individual accomplishments . . . . For one thing, cross-cultural comparisons do not always yield valid results; each individual mathematician (scientist) has been a captive of his or her own culture. Nor is it fair to judge mathematicians (scientists) wholly within the context of their own era, for discoveries and inventions considered

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[10] Aristotle, criticisms on The Republic, ii, cc 204, quoted in de Burgh, p. 185.

> trivial in one era have taken on new luster in the light of subsequent developments.[11]

Too often, what work has been produced about women (and men) and their achievements in an era or an area has disregarded Osan's observation. The result is writings that only have propagandistic and hagiographical value.

The principal source of material about women scientists before the twentieth century, with the exception of biographical studies and books that are now appearing such as Osen's, is that of H.J. Mozans', entitled Woman In Science.[12] This book first appeared in 1913 and was reprinted in 1974 with an introduction by Mildred S. Dresselhaus. This event in itself is indicative of the growing interest in the history of science and the history of women in science. As Dresselhaus pointed out in her introduction, Mozans, writing in 1913, believed that the full entry of women into the professional scientific world was imminent and this view colored his interpretation of the past. Also, although he was a careful scholar and reliable for the more modern periods, his assessment of the contributions of women from earlier periods needs to be viewed with caution.

In his first chapter, "Woman's Long Struggle," Mozans discusses the one group of women in classical Greece that were not bound by the home and were not mentioned by Plato and Aristotle in their systems. They were the hetaerae.[13] One of them, Aspasia, the companion of Pericles, was so outstanding that not only did Pericles probably rely upon her judgment, but their home was a mecca for philosophers, writers, scientists, and politicians. Though it is said that she wrote some of the speeches of Pericles, no specific contribution can be identified as hers alone.[14]

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[11] Osen, Lynn M., Women in Mathematics, Cambridge, Massachusetts, 1974, p. 2-3, (parentheses added.)

[12] Mozans, H.J., Woman in Science, New York, 1913; reprinted by MIT Press, 1974.

Mozans mentions other Greek women as being scientists in several fields, but only one of them, Hypatia (fourth century A.D.,) is discussed by both Mozans and Osen and is accepted as a real person historically. Hypatia is unfortunately known more for the fact that she was killed by the Christians for her philosophy than for the fact that she was probably the most well-educated woman of her day, an astronomer of note and a serious mathematician. Primarily, she was a teacher and a very popular one at the schools of Alexandria. However, she did write a treatise on the Conics of Apollonious which popularized and improved upon his text. Coming at the close of the Greek period, Hypatia became the last person to work on conic sections until the first half of the seventeenth century.[15]

Of importance here are two things. One, at least some women in the classical period were given educations more or less equivalent to those of men and in some cases their talents were recognized. Probably Hypatia was atypical because her father seems to have been the first person to insist on a complete and equal education for his daughter.

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[13] The hetaerae were a feature of Athenian aristocratic social life but they were neither prostitutes nor acceptable as aristocratic women. They were of non-Athenian origin and therefore not eligible for marriage to Athenian men. They became relatively well-educated and functioned as companions at gatherings. Though lacking in real legal status, neither slaves nor fully free, they functioned much like hostesses of the salons of the Enlightenment.

[14] Mozans, Woman in Science, p. 9-15, passim.

[15] Osen, Women in Mathematics, p. 21-32, passim.

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Despite the romantic glow cast over the classical era by Mozans and despite the fact that it may have been a great era for the scientist in his role as philosopher and despite the fact that it was the first age of rationalized scientific thought and scientific discovery, it was not a great era for women. Though in some periods and places Greek women had more freedom and dignity, by-in-large, regardless of class, they lived under many constraints.

The tradition that there were Greek women scientists and intellectuals remains however difficult to document. Perhaps if more of the documents from the classical era survived, a different picture would emerge. The writings of Plato and the richness of the role of women in literature suggest this. When considering the case of Hypatia, an outstanding person by any criteria, another element is introduced. Only an outstanding woman could succeed in the conditions of the classical era and even then she was considered by her contemporaries as an aberration. This has remained the prevailing view, with few exceptions, of all women scientists until the present.

In one era, the Romans differed greatly from the Greeks. Over the centuries, Roman women achieved great status within the families and politically. In the early days of the republic, the law was harsh. The family was the basic social and political unit. The elements of the civic personality of the Roman give some indication of the importance of the family. There were three essential factors - freedom, citizenship and membership in a family. The ancient Roman family was unique. All unity and power were realized in the person of its head, the father. Throughout his life, he possessed absolute authority over the persons, lives and goods of wife, sons, unmarried daughters and others connected with the household

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and could do with them as he wished. The power of the head of the state was analogous to that of the father of the family.

As time went on and Roman citizens gained more rights, the law softened with regard to families. Wives, mothers and daughters became persons at law and in the family. Unlike her counterpart at Athens and in most other countries, the Roman woman's increased status and rights rested on custom which had hardened into law, so that while the father still remained head of the family, the wife and mother gained rights, respect and responsibilities.[16] The Roman matron, as the embodiment of familial and civic virtues and responsibilities, passed into legend.

According to Mozans and traditional histories, women in Rome received an education equivalent to that of men at least through the course of ethics and Greek literature. Indeed, there was a tradition of cultivated women participating at least indirectly in political affairs by having their opinions heard and considered. Cornelia, the mother of the Gracchi, who lived in the late 2nd and early 1st century, B.C., learned and politically astute herself, educated her sons carefully, managed the vast holdings of the family and served throughout her life as political advisor to her sons. She exemplified all the virtues of the Roman woman.[17] However, Roman women were not noted for their scientific achievements in general, though they may have contributed to the medical arts. In this they reflected the values of their culture which was decidedly anti-scientific.[18]

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[16] de Burgh, Legacy of the Ancient World, p. 229-232, passim.

[17] Mozans, Woman in Science, p. 26.

[18] Mozans, Woman in Science, p. 19-30, passim.

By way of concluding the section on the ancient world, the following observations can be made: in the eras of great scientific and philosophical achievement, namely the Greek and Hellenistic period, science, a branch of philosophy, was an important part of a person's experience. However, though there were dissenting voices, in this same sense men were. Thus, any achievements they made were accomplished in spite of tremendous social pressure. Even those who were educated in Platonic and Pythagorean schools still had social pressures and custom to battle. As a result, in an era of some freedom for the privileged and much scientific ferment, women played a marginal role in all spheres but especailly in the sciences even though they were honored in literature and religion. Ironically, in Rome, while the legal and social position of women was vastly superior to that of Athenian women and there was a tradition of educating upper class females to be cultured and astute politically, because the prevailing Roman temper was anti-scientific, it was not a great age for science and women did not achieve anything in this area but then neither did Roman men.

SECTION 5

Women, Science and Society
(1920 - 1970)

Women, Science and Society
(1920 - 1970)

Introduction

Properly speaking, the period of the twentieth century in the United States for women in sciences and engineering begins with 1920 for two reasons. The passage of the nineteenth amendment extending suffrage to women in 1920 seemed to be the culminition of feminist efforts reaching back to the Seneca Falls Declaration of 1848. A new era for women seemed to lie ahead. At the same time, paradoxically, 1920 marked the high point for women in the professions until the late 1960s.[1] This paradox and the period of the twenties and thirties as it relates to women in the world of work and in the professions as well need to be examined and kept in mind because they offer insight into the dilimma faced by women who seek careers in scientific professions today.

In order to understand this paradox, the following topics will be discussed: women and the quest for social and economic equality, women and the scientific professions, and the changing nature of science in twentieth century United States. While events related to each of these topics do not always fit the same chronological framework, dividing the twentieth century into two intervals of time, 1920-45 and 1945-70.

What will appear both statistically and from the narrative is that the commonly heard phrase, "we live in a period of changing values," applies to every period of the twentieth century equally. Moreover, the role of women not only in science but socially as well reflects the complexities of this rapid change.

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[1] Chafe, William O., The American Woman, New York, 1972, Chapter Two, passim.

Another observation can be made that applies particularly to women and science. Not only has science changed profoundly in the last sixty years but so have public attitudes toward science. As a result, the role of women in the sciences has altered.

Finally, from this discussion, it should be apparent that the position of women in sciences in the seventies is an outgrowth of the ferment of the preceding decades of this century and these, in turn, can be seen as originating in the preceding eras when the value of science and technology and the role of women in Western civilization were formed and also altered.

Science in the Twentieth Century

> Science is able to remain 'pure' only so long as it is without power. Its purity diminishes in direct proportion to the growth in its relevancy to the life of the society and the vital interest of groups in the society.[1]

The general impression is that science before World War II was a kind of closed-system community and it was the impact of the war that changed it, expanded it and inextricably intertwined it with the government so as to alter its entire structure. However, this impression fails to take into account that all along in the United States there existed a strand of thinking that held that science should be "involved." Moreover, World War I and the events of the Progressive era and, finally, the challenges of the Depression had involved science, even "pure" science in virtually every institution that affected people's lives. To paraphrase Daniels, science has become largely a corporate enterprise, dependent upon government and industry for its support and subject to the same pressures (bureaucratization, centralized control and politization) as other institutions in American life. All these characteristics, Daniels demonstrates, were evident by 1940; developments since World War II have been changes in magnitude, not in kind.[2]

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[1] Daniels, George H., Science in American Society: A Social History, New York, 1971, p. 314.

[2] Daniels, Science in American Society, p. 317.

Before examining the role of women in relation to science in this period, two other aspects of the role of science in the first part of the twentieth century should be examined briefly for they bear on the participation of women. These aspects are the attitudes toward science and its changing nature in this period by scientists themselves and the ideology of science that pervaded ordinary thinking, that is the popularization of science - the nearly universal notion that scientists are not quite ordinary beings who can somehow solve all the problems that beset man.

The attitude toward science and its handmaiden technology by scientists themselves in this period can be summarized by the title of a publication submitted to the President in 1945 by Vannevar Bush. It was entitled, Science, The Endless Frontier. It contained a program for the future of science, its relationship to the government, to the public, a list of the problems that science might face and a set of practical programs by which science might achieve its goals. Interestingly enough, it was reissued by the National Science Foundation in 1960 as part of its tenth anniversary observation.[3] This clearly reveals what a magic word "science" had come to be.

On the other hand, there was a conflict inherent in what scientist thought science was and what others thought science was. In other words, to most people, science was technology or applied science, while to the "true" scientist, "real" science was "pure" science. This was a theme that ran throughout nineteenth century attitudes and thoughts about science, but it became particularly clear in the twentieth century when scientists alternately tried to pursue a path without any outside interference and tried to solve problems that confronted society because scientists were perceived by themselves and society as peculiarly fitted by the very fact of their objectivity.[4]

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[3] Bush, Vannevar, Science, the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research, July 1945, reprinted, National Science Foundation, Washington, D.C., 1960.

In 1945, an interesting book about the state of science appeared.[5] It consisted of a series of essays by various scientists. Actually, each of the essays was based on a talk given at the intermission of the Sunday afternoon broadcasts of the New York Philharmonic Symphony. The series, sponsored by U.S. Rubber, was started in 1944 and is illustrative of scientists speaking to laypeople. All of the talks reflect the notions that science is a positive good and that science and scientists are set apart somehow from the ordinary world (though what they do affects the everyday world.) [Incidentally, none of the scientists who spoke was a woman.] The reason for going into so much detail about the background of this little book is that it neatly illustrates how, though scientists might think of themselves as apart from the mainstream, how much in fact they were dependent on the public and therefore sought to make themselves intelligible to the lay world.

The introductory essay, "Science and Complexity," written by Warren Weaver, attempted to place science in the mid-forties after the changes to it during

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[4] Davis, Watson, The Century of Science, New York, 1963, Chapter 13, passim; Dupree, A. Hunter, "Influence of the Past: An Interpretation of Recent Development in the Context of 200 Years of History," The Annals of the American Academy of Political and Social Science, Vol. 327, January 1960, p. 25 (p. 19-26.)

[5] Weaver, Warren, Ed., The Scientists Speak, New York, 1945.

World War II into a historical perspective.[6] Briefly, he divided science up into three types. The first type consisted of problems of two-variable types (or at most, three or four variables) in which one variable could be held constant, which was the type of science practiced from the 17th through the 19th century. The results of that type of science had revolutionized physics and and chemistry and to a lesser extent biology and medicine (because the entities involved were more complex.)

Post-1900 science could be considered the science of "disorganized complixity" -- many variables and all of them acting randomly. Examples of these sorts of problems would range from the motions of the atoms and stars to the laws of heredity. Such problems had yielded to solutions through the use of new statistical methods.

In mid-century, according to Weaver, science was ready to attack problems in the great middle region -- organized complexity. Problems in this area of science included biological, medical, psychological and political ones. From the foregoing, it can be seen that the distinction between pure and applied science was becoming blurred. In any event, such problems would yield solution based on the application of quantitive and experimental methods and the marvelous new tools developed during the war such as computers. As with any analysis this brief, there is a tendency to oversimplify, but within Weaver's essay and in its setting are (stated or implicit) all the relationships between pure and applied science, and how both of them were perceived by both scientists and non-scientists are either stated or implied.

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[6] Weaver, "Science and Complexity," The Scientists Speak, p. 1-8.

Another illustration of how the public viewed science in the period well into the sixties, "the science will solve it all" syndrome, which seemed to be shared by laypeople and scientists alike is shown in Watson Davis' book, The Century of Science.[7] Published in 1963, the thesis of the book is quite simple. The twentieth century is the scientific century and such events as two world wars and a depression will not be for what the twentieth century is remembered. Incidentally, the only woman mentioned in this book is Marie Curie and only her picture is shown. Thus, even well into the present, science and engineering were perceived of as areas of expertise understood and practiced only by those well-versed in their intellectual demands and these persons were universally thought of as white males. Only occasionally were others able to penetrate those preserves.

The other features of twentieth century science that are of particular interest in evaluating the role of women in science today emerge from the vision of scientists as a community with its own rules, practices and values within the entire society. When science in earlier periods is examined, the evolution of this view is seen. However, during the late nineteenth century the notion of a community set apart was first really made explicit. Throughout the twentieth century, despite the ideas of involvement and the scientist as skilled solver of the problems of the world, the view of a community set apart is particularly appealing.

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[7] Davis, Watson, The Century of Science, New York, 1963. Prologue, p. 3-5, especially p. 5. The only problem facing us that David touches on is that of the population explosion and even in discussion of that problem he over-simplifies and suggests that answers to problems of that type are not in the realm of science, p. 225-232. As for atomic bombs, though he acknowledges that scientists invented them, he suggests that, "the absence of international means of controlling them is potentially disastrous to the world." p. 27.

As a result, the scientist is viewed as a professional of a "higher order" accountable only to "his" peers. They judge by how well "he" performs. The consequence of this view is more research, more papers, more learned journals, more scholarly meetings -- all within the world of the scientific speciality. The keeper of the gates to this particular scientific world is the professional society. Originating in the nineteenth century, professional societies proliferate as science divides into ever increasing numbers of specialties. For women, this rigid world which is jealously guarded, was and is, difficult to penetrate.

On the other hand, the increasing complexity of twentieth century science militates against another Marie Curie performing prize-winning experiments in her kitchen. With the expansion of the role of the university into the world of science, increasingly "pure" science came to be performed in the academic environment. This, too, is a community apart with its own rules and criteria for success and achievement. And academe also has rigorous rules about the placement of women.

Such developments raise questions about the quality of science when the scientist is always under pressure to produce. But for the twentieth century woman scientist another question is posed. How well can "she" fit into these tightly organized communities that constitute the modern scientific world? This question is discussed when the role of women in twentieth century science is analyzed.

Yet another feature of present-day American science is the fact that, "the lone scientist has given place to the research-team. Government, industry, and university are now frequently found as a troika, yoked together for the accomplishment of science projects."[8] Thus science now plays a major role and scientists have much at stake to perpetuate a system which gives them power, prestige and economic reward. Though this development is not new, it is now dominant -- science is big business. This, too, has consequences for the female scientist.

A final feature of present-day scientific activity in the United States is its relatively new and rather differently structured ways of communication within the scientific community. While the sterotype of the scientist in his lonely laboratory discovering the secrets of the universe does not fit the present situation, and the description of science as existing in a kind of vacuum no longer is appropriate, an exact description of what it is, especially as an institution, is elusive. One of the more interesting attempts to characterize science in a "scientific" way is the book, Little Science, Big Science, written by Derek J. Prince in 1963. The book, seriously flawed in its methodology, received mixed reviews.[9] Despite the fact that Price does not really define "big science", that is science in the last half of the twentieth century, he offers relatively accurate pictures of a portion of the scientific milieu into which women scientists must fit themselves if they are to be deemed "successful." Price tries to treat science as a measurable entity, an effort that is not satisfactory, but his insights, when he is not trying to quantify science, are pertinent.

Before discussing the one that is more relevant to the role of women in science, it is worth mentioning that in the section where he grapples with the problem of ensuring a supply of top-quality scientists. (One of the themes of his book is that there are more than enough scientists, but that there is no way of ensuring a sufficient supply of truly original and creative persons.) In so doing, asks rhetorically, "Is it possible that the level of good scientists cannot rise by the factor . . . that we have presumed?" He goes on to note, "Almost half of the factor is accounted for by the wastage of scientific womanpower, a wastage that the U.S.S.R. has partially checked but that we seem unable to avoid."[10]

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[8] Bates, Ralph S., Scientific Societies in the United States, Cambridge, Mass., 1965, Third Edition, Preface to the Third Edition.

[9] Price, Derek J., Little Science, Big Science, New York, 1963, p. vii-ix; Goldberg, Stanley, Review, Science, May 10, 1963, p. 639-641.

Related to this wastage, though Price does not make the connection, is his analysis of the present scientific community in his chapter on "Invisible Colleges and the Affluent Scientific Community." Though recent events might belie the latter part of the title, the notion of "invisible colleges" has importance when considering the role of women in the scientific community. Price approaches this idea through the usages of the scientific paper and the scientific journal by pointing out that these are social devices as well as additions to the world of scientific knowledge.[11]

He relates the journal, the scientific article with the purpose of scientific meetings and groups of scientific persons working informally together. Because of the proliferation of journals and papers (many of them derivative or similar to other work), that necessary element of science -- communication with one's colleagues -- gave rise not only to the scientific meeting but also to the special conference or series of seminars where a few (Price says at most around 100) meet to discuss and work on specific topics. These unofficial organizations, in addition to the regular scientific meetings, play a necessary part in a person's scientific career for it is at these meetings where the scientist becomes "known" and is taken into the "network" of science.[12] As will be demonstrated in another section of this work, women have difficulty in gaining access to this network which is vital to a full professional career in the sciences and engineering.

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[10] Price, Little Science, Big Science, p. 54.

[11] Price, Little Science, Big Science, p. 65, 68.

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This summary of the state of science in the twentieth century is not intended to be exhaustive but rather to be indicative of the nature of the present day scientific institution in which women must gain access in order to pursue careers in science. Most particularly, the aim of this sketch was not to follow the celebratory school of writing about science and comment upon the spectacular discoveries that have altered the nature of society and science itself, but rather to set forth the nature of the institution and illustrate its status as a source for solutions to the problems of society and the ills of mankind.[13]

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[12] Price, Little Science, Big Science, p. 84-85.

[13] One has only to examine the hagiographical and romantic books that were appearing about scientists in the era. For example, Paul de Kruif, The Microbe Hunters, 1921.

WOMEN AND SOCIAL AND ECONOMIC EQUALITY, 1920-1960

The success of women in the fields of the sciences and engineering is dependent on the position of women as defined by the social mores of the particular period in which they live. At the same time their success in their chosen occupations is also dependent on economic factors. As is discussed in another part of this analysis, the nineteenth century witnessed the struggle by women for equality in all spheres. However, by the first two decades the majority of women involved in the first feminist movement had settled for political equality -- the vote. Their reasoning was that as a result of gaining the right to vote, they would then be able to obtain equality in other areas. A minority of the feminists of this era insisted that economic and social equality were the important areas of their struggle for full equality.

In effect, what this latter group of feminists was saying was that without basic changes in attitudes toward the role of women in the economic and social spheres little would change. To them it was by no means clear that the ballot would provide the way to true equality.[1]

In the decade of the twenties the question of whether true economic equality was being achieved was confused. The twenties witnessed a "revolution of manners and morals" and the census of 1920 counted over

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[1] William O. Chafe, The American Woman, New York: Oxford University Press, 1972, p. 48.

8 million females employed in 437 different job classifications.[2] Many people at the time and since then have tended to confuse the two events and attribute the "revolution" to the employment of women.[3] Most textbooks have portrayed the new age as "characterized by an unprecedented speed-up of women's involvement in the labor force. In general, the consensus has been that women achieved a substantial amount of the economic equality which the feminists had sought and in the process experienced a new degree of freedom from the restrictions which had formerly bound them."[4]

On the surface this would seem to be an acceptable observation. However, it does not take into account the following factors: the types of women participating in the labor force, the types of work they did and under what conditions, and who were the participants in the "revolution of manners and morals."

Though the numbers of women in the labor force grew over 26% in the decade of the twenties, most of the growth was in two areas -- clerical and sales.[5] Therefore, if the words "economic equality" or "emancipation" are taken to mean the ability of women to function in the world outside the home on the same basis as men, then women were not emancipated by the development in the decade of the twenties.

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[2] Chafe, The American Woman, p. 49.

[3] Frederick Lewis Allen, Only Yesterday, New York: Bantam edition, 1959, (first published 1931), pp. 68, 76. Allen's view is the prevailing one.

[4] Chafe, The American Woman, p. 50.

[5] Chafe, The American Woman, p. 50.

Moreover, the occurrences of the decade of the thirties (the central event of which was the Great Depression) did little to improve the economic equality of women. In fact, the feminist dreams receded. A "revolution of manners and morals" may have taken place; women may have entered new areas of work and more of them may have been working (partly because of increased population), but the real revolution took place in the decade prior to World War I as will be discussed in another section.

Before considering the effects of the Depression on the quest of economic equality, a brief description of the characteristics of the female labor force in the period under consideration is in order. In the 1890's the average female employee was single and under twenty-five. She worked for six or eight years and then married, leaving her job in the process. From 1900 to 1940, however, the median age rose to over thirty and the proportion of females 24 to 44 who were employed grew from 18.1% to 30.6%. Moreover married women entered the labor market substantially. In 1900 only 5.6% of the women who were married worked; the percentage was 10.7 in 1910 (emphasizing again that that was the critical decade); by 1930 married women constituted 11.7%; and by 1940 the percentage was 15.2%. Thus married women joined the labor force at a rate five times faster than that of other females and comprised 35% of all women employed in 1940, in contrast to 15% in 1900.[6]

However, the influx of married women into the labor market had little to do with economic freedom for the two periods that accounted for the greatest part of the growth were the decades of 1910 (when immigrant women in large numbers went into the sweatshops) and 1930 when women were forced to work because of economic need. It must also be emphasized that these women had the most menial sorts of jobs, domestics and personal service, the apparel industry and canning factories. By way of emphasis, in 1940 only 5.6% of married women held jobs if their husbands earned over $3,000 a year, but 24.2% worked if their husbands received less than $400. Another facet, often overlooked when regarding this period as one of economic emancipation for females, is the composition of the female working force. As late as 1930 over 57% of all employed women were either blacks or foreign-born whites.[7] Thus, by any measure, women in general did not achieve the dream of the economic feminists.

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[6] Chafe, The American Woman, p. 56.

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[7] Chafe, The American Woman, p. 57.

Women in the Professions in General

> The 1920's, 1930's and 1940's also witnessed the fruition of individual women as scholars in the arts and sciences. In 1920 the overall percentage of women Ph.D.'s was at its highest point, and at the start of the decade there seemed to be a momentum that would carry women further and further in academic and other professional activities. As we all know, this expectation was far from realized.[1]

The changing economic role of women in the period prior to World War II and the changing role of science and how it was viewed have been examined but what has not been discussed is the role women occupied relative to science -- in other words were there any women scientists and if so, what was their status? This is a complex topic and a simple recital of numbers would not reveal the subtleties involved. What is involved is not only the role of the woman scientist but of the role of the woman professional (of which the scientist is a subset) and the parts played by social values and education on participation of women in the professional and scientific world.

While the suffrage movement in conjunction with the Progressive Movement had achieved much in the way of legislation favorable to the interests of women in general and in the area of improving working conditions especially, by mid-decade, the momentum of such efforts was lost and women's standing in the eyes of politicians dropped precipitously.[2]

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[1] Barbara Miller Solomon, "Historical Determinants and Successful Professional Women," Women & Success: The Anatomy of Achievement, Ruth B. Kundsin, ed., New York, William Morrow & Co. 1974, First publ. 1973, pp. 185-193. Quote pp. 190-191.

[2] W. H. Chafe, The American Woman, p. 21.

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The effect was dismaying to the women involved. It could, in part, be attributed to a conservative shift in politics symbolized by the election of Calvin Coolidge in 1924. But the main reason, politically, was that female citizens did not behave as a cohesive and committed bloc which the suffragists had predicted. This is clearly demonstrated by the statement of a Democratic Committee woman, 'I know of no woman today who has any influence or political power because she is a woman. I know of no woman who has a following of other women. I know of no politician who is afraid of the woman vote on any question under the sun.'[3]

What happened was that instead of voting as a bloc, those women who voted (and most did not) followed the lead of the dominant male in their families. Also they lacked encouragement within their families to vote. Finally, there was no overriding "woman's issue" around which women could coalesce.[4]

This loss politically was reflected in the loss of status and representation of business and professional women in the 1920's and 30's. These were just the women who were expected to benefit so much from the suffrage amendment and the ones on which the economic suffragists had pinned their hopes for the realization of true equality. The role of women in the sciences is inextricably bound up with that of professional women in general even though they constituted as will be seen a tiny minority within the professions just as professional women were a minority themselves.

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[3] Quotation taken from Chafe, The American Woman, p. 21.

[4] Chafe, The American Woman, pp. 30-31.

In addition to loosing status politically, professional women lost status socially (if they had ever truly had it). In part it was due to that popular image of the twenties — the flapper. Articles on the flapper gave the impression that women had entered a new era of economic emancipation as well as social emancipation. She was depicted as working by day and playing by night -- in short truly free. As will be shown this was not so.

Despite the fact that serious professional women were not the same as single clerical workers, having freedom and fun for the first time, they somehow were intertwined in the public mind to the detriment of the professional woman. The main reasons for this was the public's unwillingness to think of women as equal participants in the labor force.[5]

The most pernicous form that this thinking took was the misconception that women worked for pocket money. Since women worked to spend their money on frivolous things and to indulge their desires, then the inequalities from which they suffered were justified.

Though it has been noted earlier that married women worked out of necessity and the Women's Bureau investigations during the 1920's and 1930's underscored this by reporting that approximately 90% of employed females worked because of economic need and that the group which had the highest percentage of women working, minority and immigrant women, were the most in need.[6] Clearly the money they earned was not 'pin money.'

However, the notion of women working for frivolous reasons worked to the detriment of professional women as well. Government spokesmen (including the Women's Bureau), employers and public opinion insisted that women belonged in the home and that married women's employment represented a dangerous aberration (a carry-over from earlier thinking). On all sides women were told that the welfare of the home and the family was the job for which women were intended and was a "woman-sized job in itself." Moreover, if women worked, they endangered the happiness and health of the home itself.[7] Faced with arguments such as these from every source, it took dedicated women, or economically desperate women, to claim the right to choose to work and to be regarded as full participants in the world of work -- man's world.

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[5] Chafe, The American Woman, p. 61.

[6] Chafe, The American Woman, p. 63.

These arguments were not new nor would they disappear. Women today who work or who choose careers are still faced, perhaps in more subtle ways, despite all of the intervening events, with the pressures exerted by the old social norm that a woman's true career is in the home.

If the professional structure of 1900 had prevailed, by 1920 women would have constituted well over 40% of all professions. But such an event did not happen. This does not mean that they would have been distributed evenly throughout the professions, however. Also, the proportion of women in the labor force has grown steadily for many decades. However, the proportion of women in the professions -- which in terms of educational requirements and income constitute the upper range of the career ladder reached a peak in 1930 and thereafter declined, but recovered slightly in the last decade.[8]

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[7] Chafe, The American Woman, pp. 63-65 passim.

[8] Rudolph C. Blitz, "Women in the Professions, 1870-1970," Monthly Labor Review, May 1974, vol. 97, no. 5, pp. 34-39.

Blitz's analysis of the participation of women in the professions from 1870 to 1970 complements that of Chafe's. Both suggest enormous growth, relatively speaking, for women in the professions in the early part of this period. But they both note that the professions were heavily sex-segregated. Most of the growth took place in teaching and nursing -- careers deemed suitable for women because they could be considered as a kind of extension of woman's role in the home.[9]

In 1890 the professions were dominated (for both male and female) by five categories that made up 73.5% of the total. Two of them are of special interest. Only one of these professions, physicians, surgeons and healers, could be considered science-related. And physicians, ranking second, constituted only 11% of the total and women within that category (excluding nurses and midwives) made up less then 5% of the total.[10] Interestingly enough, the group that ranked highest in percentage of the total profession class (38.8%) was the category, elementary school teachers, a heavily female-dominated field.[11]

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[9] An interjection is needed here. While both Chafe and Blitz tend to rely on the same sources for their basic data, Chafe weaves into a narrative and his main intent is not a statistical examination. On the other hand, Blitz, whose main purpose is to show that the gap between men and women professionals "is now widening" relies on a heavily statistical and technical analysis to present his argument. Chafe, The American Woman, p. 90 and Blitz, Monthly Labor Review, p. 35.

[10] Blitz, Monthly Labor Review, pp. 35, 37.

[11] Blitz, Monthly Labor Review, p. 37.

By 1970 the position of these categories had changed precipitously. The percentages of the professional categories were as follows: elementary school teachers 13.6% and physicians, surgeons and healers 3.3%. What had happened was that new categories of professionals had emerged such as formalized nursing (which Blitz mentions) and scientists and engineers (to which Blitz refers in passing but does not examine their relative changes in status between 1890 and 1970). According to Blitz, however, this phenomenon had taken place by the 1950's and remains essentially unchanged.[12] This interpretation, based on a variety of sources and a complex definition of professional fields does agree with that of Chafe in that it emphasizes that women as professionals "lost out" earlier than is generally supposed even though they had started out relatively well as compared to other working women in relation to males.[13]

Another way to guage the status of a professional is by the amount of post-secondary education that person obtains. According to Blitz,

> The historical changing ratio of academic degrees conferred to the male population 25 years and over and the similar female population, respectively, gives some approximation about the relative supply of the two sexes for professional jobs. From 1900 to 1940, this proportion grew much more rapidly for women than for men--at rates of 5.0 and 2.2 per cent respectively. During the postwar years (1948-70), the growth rates for both groups slowed down substantially and their positions were reversed, so that the proportion of women receiving degrees grew less rapidly than the proportion of men--2.3 and 3.5 per cent respectively. . . Thus, the gap between men and women is now widening.[14]

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[12] Blitz, Monthly Labor Review, p. 37.

[13] Blitz, Monthly Labor Review, p. 24.

[14] Blitz, Monthly Labor Review, p. 37.

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The Extent of the Participation of Women
in the Sciences and Engineering
At Present

A Demographic Approach

Natalia Meshkov

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SECTION 1

Introduction

In this work the current participation of women in sciences is evaluated and analyzed. All fields of natural and social sciences are covered including mathematics and engineering. The approach is a demographic review. Numerous existing published and unpublished studies form the basis of this review.

The time period in this work is primarily from the late 1960's to the present. Data from earlier periods are included only when such data have a direct bearing on the current status of women scientists. While some work has been done on this topic before this period, it is only in the last five years that the extent of participation of women in sciences has been studied extensively. Quantities of data have been collected, and numerous published and unpublished studies with important interpretive conclusions are being produced. It is also in this particular period that many events have happened to affect the participation of women in sciences. Legislation prohibiting sex discrimination has been passed; efforts have been made to increase the number of women entering scientific professions; "affirmative action" plans have been instituted; women have become increasingly organized; and at the same time the economic resources have been shrinking.

Throughout this work the data on women scientists are compared with those of men in the same fields. It is only in this way that any meaningful evaluation of the relative status of women in science can be made. In addition, in order to assess the change in relative status of women scientists over the recent years, the data are compared over a number of years, whenever possible.

The sources of the data used in the present work will be described here in general terms. References and a detailed discussion of the sources will be given in the following sections. These sources fall into several broad categories. First of all, there are national surveys designed to study the scientific and engineering population as a whole. Such surveys have been conducted for many years, but it is only recently that a systematic collection of data on women was included in them. Thus, the National Research Council of the National Academy of Sciences conducts a bi-annual survey of its Roster of Doctoral Scientists and Engineers, collecting a wide variety of data pertaining to their fields, employment status, salaries, etc. Other surveys of this type are the 1972 "Post-Censal" survey, which collected data from a national sample of persons identified in the 1970 census as working in the scientific, engineering and technical occupations, and the 1970 National Register of Scientific and Technical Personnel, prepared by the National Science Foundation. They cover both the doctoral and non-doctoral population. The data from these surveys are used extensively in the present work.

Another type of data source is a survey designed to study some broad subset of professional population. For example, the American Council on Education conducted two surveys of the teaching faculty in academe, one in 1968-69, and another one in 1972-73. These surveys could be very useful for the purposes of this study because one could compare the status of academic women over a period of five years. However, the published reports based on this survey did not treat scientists as a separate group; original survey data would have to be analyzed in order to obtain specific data on scientists. Another survey of this type is a recent study by John A. Centra in which the male and the female doctoral population is surveyed. While his report contains some data on scientists, most of it deals with the doctoral population as a whole. Sources of this type are used in this work to compare with or complement the data of other sources.

There are also surveys conducted by professional associations. Thus, the American Chemical Society and the American Society of Microbiologists conduct regular periodic surveys of their respective memberships. The results of these surveys are published in numerous reports. This work draws heavily on their findings. Other societies also conduct surveys of their membership, but most of these are not as extensive as those of chemists and microbiologists and do not contain quite as much information that is useful for this review.

In recent years, women in various professions have organized committees and caucuses both within and outside of their professional associations. Women's committees were also formed on campuses of many colleges and universities. These groups produced numerous reports dealing with the status of professional women. Most of our present knowledge on the status of women in the professions in general, and in sciences in particular, derives from these reports. However, the data in many of these reports are derived from the more general sources mentioned above. For this reason the data obtained from the professional women's groups are cited in this work only if they originate from independent surveys. The data from campus reports were analyzed and summarized in several publications by Lora H. Robinson. Robinson's work is described in section 5 of this paper.

There are two main sources of educational data. One is the "Earned Degrees Conferred" series prepared by the Office of Education of the US Department of Health, Education and Welfare; it was used in the present work for data on bachelor's and master's degrees. The other is the Doctorate Record File maintained by the National Research Council of the National Academy of Sciences; the latter was used for the data on doctoral degrees.

Two other excellent recent works on women scientists should be mentioned. One is a demographic paper by Vera Kistiakowsky on "Women in Engineering, Medicine and Science". It was prepared in 1973 for the National Research Council Conference on Women in Science and Engineering. It contains a large amount of valuable information on the status of women in various scientific professions. The other is the 1975 work by Betty Vetter and Eleanor Babco called "Professional Women and Minorities, A Manpower Resource Service". The latter work presents data on women and minorities in different professions in the form of statistical tables and graphs. Both of these sources proved very useful in the present work.

The present paper is organized as follows. Section two is an overview of women in the sciences. It presents and analyzes data on the numbers and percentages of women in various scientific fields, on the distribution of men and women by their educational attainment and by age.

Section three examines the patterns and trends in education of women and men scientists and engineers. It also contains some data on the relative ability of men and women scientists and on the financial support available to them during their studies. The extent to which men and women educated in science and engineering participate in the scientific work force is discussed in section four. This section also analyzes and compares their unemployment and underemployment rates, as well as field switching.

The work patterns and the professional status of women scientists is examined and compared in section five. Comparisons are made by types of institution and by types of work. A detailed analysis of salaries is presented. The relative status of women scientists in academic institutions is discussed in detail. The summary of the findings of this report are presented in the concluding section.

SECTION 2

Women in the Sciences: An Overview

Women are a small minority among scientists and engineers. Tables 2.1 and 2.2 present, in our opinion, the best currently available overall estimates of numbers and percentages of women in engineering and the sciences. Two principal sources were used for these tables. Both sources are surveys designed to study the scientific and technical population in USA in 1972. Table 2.1 is based on the post-censal survey - the 1972 professional technical and scientific manpower survey.[1] It gives estimates of total number of scientists and engineers, and the numbers and percentages of women by field for all levels of educational attainment. Table 2.2 presents similar data for doctorate-level scientists and engineers. The estimates in this table are obtained from the 1973 survey conducted by the National Academy of Sciences-National Research Council (NAS-NRC) on a sample drawn from the NRC Roster of Doctoral Scientists and Engineers.[2]

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[1] The data in this survey were collected in 1972 from a national sample of persons identified in the 1970 Census as working in the scientific, engineering and technical occupations. Based on this survey, three reports were prepared. These are: "Selected Characteristics of Five Engineering and Scientific Occupational Groups: 1970 and 1972," NSF 73-306, National Science Foundation Resources Studies Highlights, Washington, D.C.;"Persons in Engineering, Scientific and Technical Occupations: 1970 and 1972", Series P-23, No. 45, Bureau of the Census; and Characteristics of Persons in Engineering and Scientific Occupations: 1972, Technical Paper No. 33, Washington, D.C. It was subsequently decided to redefine the scientist-engineer population of this post-censal survey (see "The 1972 Scientist and Engineer Population Redefined," NSF 75-305, National Science Foundation Resources Studies Highlights, Washington, D.C.). This redefinition resulted in significant changes in the data. Only data based on the redefined population are included in this paper. These revised data were made available by the Division of Science Resource Studies of the National Science Foundation and are published in Demographic, Educational and Professional Characteristics, The 1972 Scientist and Engineer Population Redefined, Volume 1, NSF 75-313, Washington, D.C.

An examination of the data in Table 2.1 shows that out of 1.34 million scientists and engineers, 73 thousand are women or about 6% of persons identified in these professions. Engineers constitute 63% of this group and the percentage of women in engineering is less than 1%. When engineers are omitted from population, women comprise about 15% of the remaining natural and social scientists. Comparing these figures with the participation of women in the total labor force, 40%[3], it is evident that women are greatly under-represented in scientific and engineering professions. Women constitute a larger proportion of social scientists than of natural scientists. Twenty-nine percent of psychologists and twenty-four percent of social scientists are women; they are sixteen percent of life and

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[2] The 1973 NAS-NRC survey of doctoral scientists and engineers and some of its results are described in greater detail in the following publications: Doctoral Scientists and Engineers in the United States, 1973 Profile, National Academy of Sciences, Washington, D.C.; and Characteristics of Doctoral Scientists and Engineers in the United States, 1973, NSF 75-312-A, Washington, D.C. The results presented in this paper are derived from the data in the above two publications and from the unpublished data derived from the tapes in the possession of the National Research Council and made available by the NRC Commission on Human Resources.

[3] "Women Workers Today," Women's Bureau, U.S.Department of Labor, Washington, D.C., 1974.

and mathematical scientists, eleven percent of computer specialists and eight percent of physical scientists.

Table 2.2 presents data on doctorate scientists and engineers by field, sex and race.[4] Women comprise a much smaller fraction of doctoral scientists than they do of scientists at all levels of educational attainment. Out of about a quarter million doctoral scientists and engineers, 21,000 are women or 8.7% of the total. Again, the highest representation of women occurs in psychology. About one-fifth of doctorate psychologists are women. Next come life and social scientists, with women comprising 12% and 11% of the respective fields. Women are 7.4% of mathematical scientists, 4.5% of physical scientists, and about 3% of computer specialists and environmental scientists with doctoral degrees. The smallest representation of women is again in engineering; 0.4% of doctoral engineers being women.

Median ages of scientists and engineers for all levels of educational attainment are shown in Table 2.3 by field and sex. It is seen that female scientists tend to be younger than their male counterparts.

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[4] While the post-censal survey also gives estimates of numbers and percentages of doctorate scientists and engineers by sex, these estimates differ considerably from those derived from the NRC data. Thus, the post-censal survey gives 170,000 for the total number of Ph.D. scientists and engineers, and 12,500 for the number of women. This should be compared with the corresponding estimates of 245,000 and 21,300 from the NRC data. Differences in the definitions of scientists and engineers and in the survey procedures may account for some of these discrepancies. Since the NRC survey was designed specifically to study the doctoral population, and since its sample was derived from the Roster of Doctorate Scientists and Engineers, it is believed that its estimates represent the actual population of doctoral scientists and engineers more faithfully than those of the post-censal survey - redefined.

In contrast with the scientists and engineers of all educational levels, women doctorate scientists tend to be slightly older than their male colleagues. The median age of women doctorates is 42.9 years compared to 41.5 years for men. The age distribution of doctoral scientists and engineers is given in Table 2.4. Figure 2.1 shows the age distribution differences between sexes. It is seen that from age 35 on, the percentage of women in a given age group increases with age from 7.3% for 35 to 39 year olds to 14.7% for those over 65. This pattern is reversed for younger scientists. For ages below 35 years the proportion of women scientists increases with decreasing age. Almost 11% of doctoral scientists 29 or younger are women. Several factors contribute to the age distribution differences between men and women doctorate scientists. As will be seen in the following section, the percentage of women Ph.D. degree recipients decreased steadily from the twenties and reached a minimum in the fifties, with a subsequent increase from the fifties until the present. This,plus the fact that women in general tend to live longer than men, help explain why there are comparatively more older women scientists. The increase of women in the younger age group corresponds to the recent increase in women Ph.D. recipients.

Table 2.2 also shows the representation of minorities among the doctoral scientists and engineers. The table gives data only for Asians and Blacks. The numbers for the American Indians and "other" were too small to warrant inclusion in the table. Of the total 106 American Indian scientists, 3 were women and of the 315 "other", 34 were women.

Figure 2.2 shows educational attainment of scientists and engineers calculated from the post-censal survey data.[1] On the whole, women scientists and engineers are less likely than men to hold doctoral degrees and more likely to hold bachelor's and master's degrees.

While women scientists constitute a small minority, they do exist in significant numbers. There are 73 thousand women scientists and engineers. Data on recent Ph.D. recipients indicate a sharp increase in the proportions of women. These trends among others will be discussed in the following section.

Table 2.1

Scientists and Engineers by Sex and Field
(All degree levels)

Field	Total Number	Number of Women	Women % of Total
Total	1,336,458	73,090	5.5
Physical Sc.	179,812	14,551	8.1
Chemists	104,413	11,424	10,9
Physicists	33,896	1,469	4.3
Earth & Marine	31,929	830	2.6
Other Phys. Sc.	9,574	829	8.7
Math. Sc.	31,132	5,059	16.2
Mathematics	19,217	3,023	15.7
Statistics	11,916	2,036	17.1
Computer Sc.	100,309	10,673	10.6
Operations Research	11,821	526	4.4
Engineers	840,305	4,925	0.6
Life Science	77,163	12,276	15.9
Biolog. Sc.	30,325	6,369	21.0
Agric. Sc.	30,383	224	0.7
Medic. Sc.	16,454	5,683	34.5
Psychology	36,684	10,716	29.2
Social Science	59,232	14,364	24.2
Economists	21,738	2,404	11.1
Soc/Anthrop.	11,230	2,826	25.2
Other Soc. Sc.	26,264	9,133	34.8
Total (less Engineers)	496,153	68,165	15.4

Source: "The 1972 Scientist and Engineer Population Redefined, Volume 1, Demographic, Educational and Professional Characteristics", NSF 75-313, Washington, D.C., May 1975.

Table 2.2

NUMBER OF DOCTORAL SCIENTISTS AND ENGINEERS BY FIELD, SEX AND RACE

	Total			Black			Asian		
Field	Total Number	Number of Women	Women % of Total	Total Number	Number of Women	Women % of Total	Total Number	Number of Women	Women % of Total
TOTAL	244,921	21,261	8.7	1,860	249	13.4	11,001	837	7.6
Physical Science	53,425	2,486	4.7	419	17	4.0	2,520	193	7.7
Chemists	33,881	1,950	5.8	375	17	4.5	1,481	166	11.2
Physics/Astron.	19,544	536	2.7	44			1,039	27	2.6
Math Science	13,515	992	7.3	103	17	16.5	653	61	9.3
Mathematics	11,984	915	7.6	103	17	16.5	554	51	9.2
Statistics	1,531	77	5.0		-		99	10	10.1
Computer Spec.	2,943	90	3.1	29	-	-	124	3	2.4
Environmental Sc.	11,074	307	2.8	23	-	-	314	5	1.6
Earth Sc.	9,142	236	2.6	23	-	-	257	4	1.6
Oceanography	1,227	54	4.4	-	-	-	23		
Atmospheric Sc.	705	17	2.4	-	-	-	34	1	2.9
Engineers	37,569	165	0.4	87	1	1.2	3,141	23	.7
Life Science	64,540	7,697	11.9	579	74	12.8	2,770	413	14.9
Biolog. Science	41,035	6,214	15.1	453	70	15.4	1,832	338	18.4
Agric. Science	11,893	175	1.5	26			295	20	6.8
Medic. Science	11,612	1,308	11.3	100	4	4.0	643	55	8.6
Psychology	28,286	5,777	20.4	247	95	38.5	308	63	20.4
Social Science	32,773	3,582	10.9	362	43	11.9	1,169	76	6.5
Economists	9,678	610	6.3	101	5	5.0	461	6	13.0
Socio./Anthrop.	7,455	1,444	19.4	122	26	21.3	225	32	14.2
Other Soc. Sc.	15,640	1,528	9.8	139	12	8.6	483	38	7.9
No Report	796	165	20.7	11	2	18.2	2	-	-
TOTAL (less Engineers)	207,352	21,096	10.2	1,773	248	14.0	7,860	814	10.4

Source: "Characteristics of Doctoral Scientists and Engineers in the United States, 1973", NSF 75-312-A, Washington, D.C. 1975 (Based on data from the 1973 Survey of Doctoral Scientists and Engineers)

Table 2.3

PERSONS IN THE 1970 EXPERIENCED CIVILIAN LABOR FORCE IDENTIFIED AS SCIENTISTS AND ENGINEERS, BY SEX AND AGE: 1972

Field of Identification	Total (000's)	Men Number (000's)	Men Median Age	Women Number (000's)	Women Median Age
Engineers	840	836	41	4	36
Mathematical Specialists[1]	31	26	36	5	35
Computer Specialists	100	90	34	11	29
Operations Research Analysts	12	11	35	1	33
Life Scientists	77	65	39	12	35
Physical Scientists	180	165	40	15	35
Psychologists	37	26	37	11	38
Social Scientists	59	45	38	14	36

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[1] Includes mathematicians and statisticians.

Note: Detail may not add to totals because of rounding.

Source: NSF Science Resources Studies Highlights, "The 1972 Scientists and Engineer Population Redefined", NSF 75-305, April 11, 1975, Washington, D.C. 20550.

Table 2.4

AGE DISTRIBUTION OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX

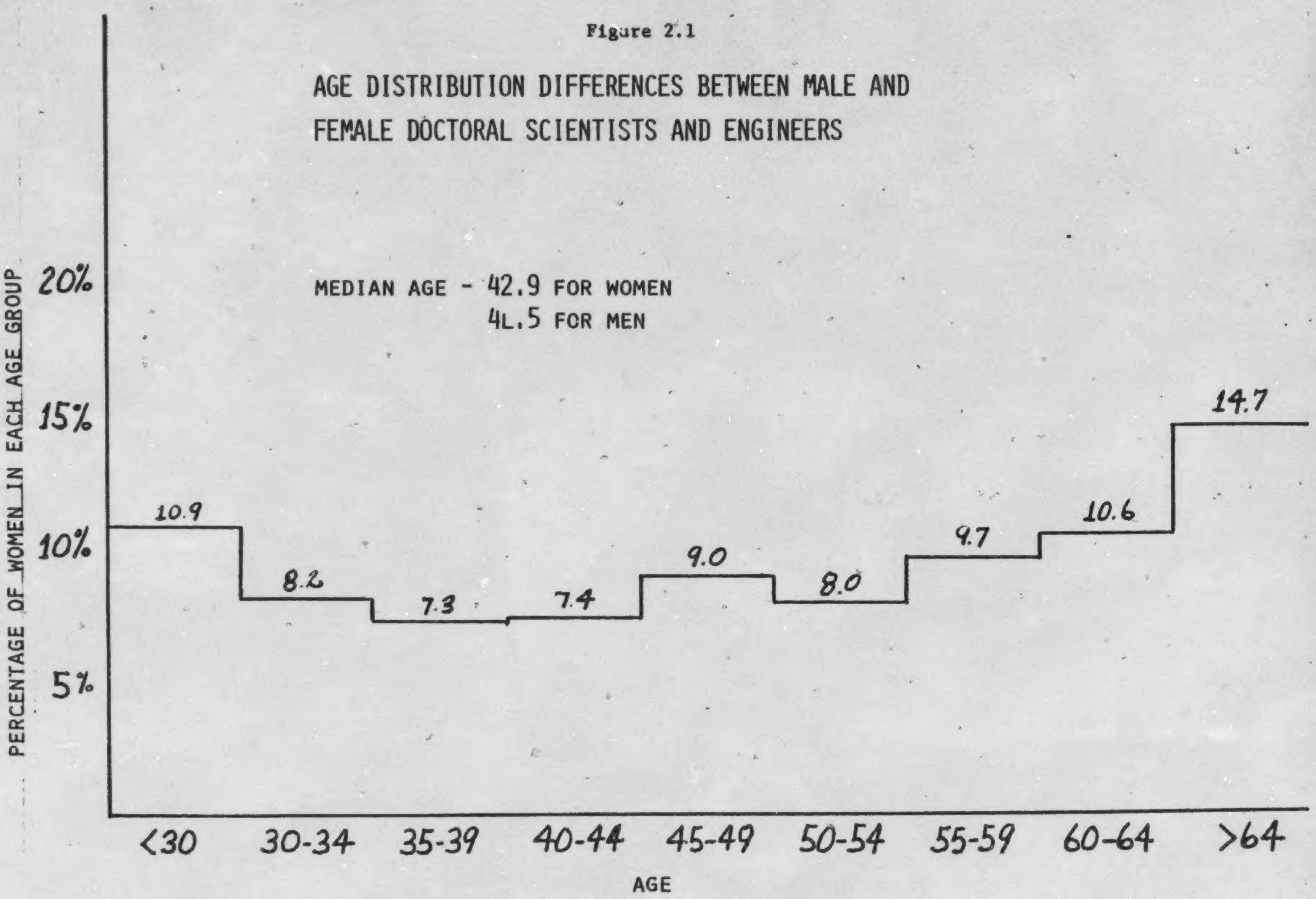
Age	Men %[1]	Women %[1]
Under 30	4.3	5.6
30-34	22.2	21.0
35-39	18.8	15.7
40-44	15.7	13.3
45-49	13.0	13.6
50-54	10.5	9.7
55-59	6.8	7.7
60-64	4.1	5.2
65 and over	4.5	8.2
All ages	100.0	100.0
Median age in years	41.5	42.9

[1] Percentages are computed only for those reporting their age: 0.2% of men and 1.1% of women did not report their age.

Source: 1973 NAS-NRC survey of Doctoral Scientists and Engineers.

Figure 2.1

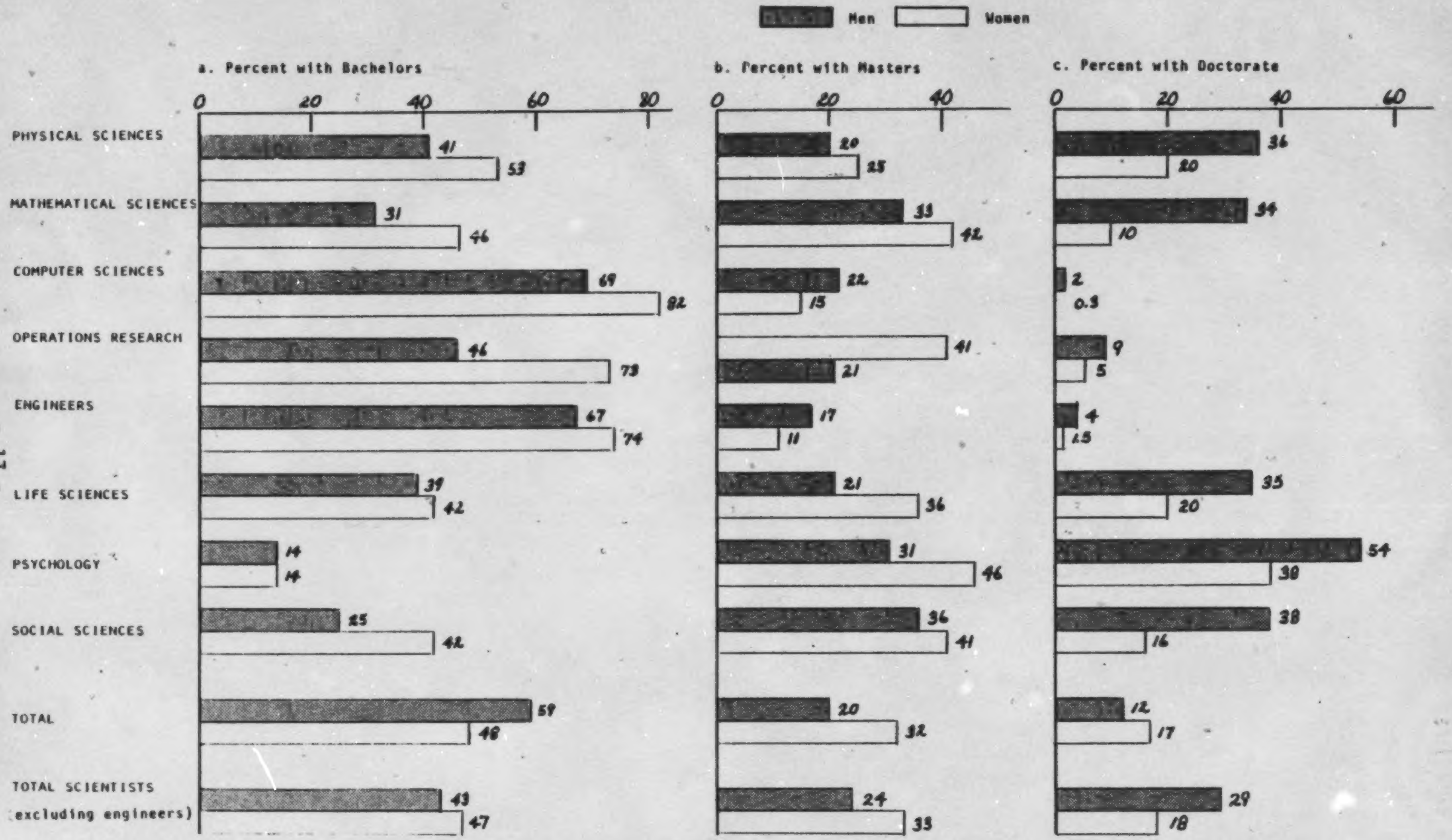
AGE DISTRIBUTION DIFFERENCES BETWEEN MALE AND FEMALE DOCTORAL SCIENTISTS AND ENGINEERS



Source: NAS - NRC Survey of Doctoral Scientists and Engineers, 1973

Figure 2.2

EDUCATIONAL ATTAINMENT OF SCIENTISTS AND ENGINEERS BY SEX AND FIELD *



*Percentages do not add to 100 because persons with less than bachelor's are included in the population.

Source: "The 1972 Scientist and Engineer Population Redefined, Volume 1, Demographic Educational and Professional Characteristics", NSF 75-313, Washington, D.C., May 1975.

SECTION 3

Educational Patterns and Trends

Patterns and trends in education of women and men scientists and engineers will be examined in this section. From the previous section, it is apparent that only a very small fraction of persons in scientific and engineering professions are women. This is due in part to the fact that fewer women are educated as scientists. However, that is only a partial answer in that the proportion of women educated as scientists is considerably larger than might be expected from their participation in the scientific labor force, especially among non-doctorate population.

Tables 3.1, 3.2 and 3.3 show data amassed on bachelor's and master's degrees awarded in science and engineering by field, sex and year of degree from 1947-48 to 1973. Tables 3.4 and 3.5 show doctorate degree recipients in science and engineering from 1920 to 1973.[1] The predominant pattern in these tables is that the more advanced the degree, the smaller the fraction of women among the degree recipients. Thus, between 1947 and 1973, 22% of bachelor's and 14% of master's degrees in science and engineering went to women; the percentage of doctorate degrees awarded to women in scientific and engineering fields is about 9% between 1920 and 1973. This discrepancy is most striking in mathematics: one-third of all bachelor's degrees in mathematical sciences (mathematics, statistics, computer science) are awarded to women; only 7% of doctorates are awarded to women.

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[1] The data on degrees awarded originate from two different sources. The data on bachelor's and master's degrees come from the Earned Degrees Conferred series prepared by Office of Education in the U.S. Department of Health, Education and Welfare. These data have been available by sex only since 1947-48. The data on doctoral degrees come from the Doctorate Record file maintained by the National Academy of Sciences National Research Council since 1920.

At this point it is worthwhile to examine the data on bachelor's and master's degrees in more detail. Table 3.1 gives these data by year of degree and broad field category.[2] It is apparent that in each field there has been an increase in the proportion of women awarded bachelor's degrees from the late 1940's and 1950's to the 1970's. An interesting trend can be observed over the last three years (1970-71 to 1972-73). There is an increase in the percentage of women bachelor's degree recipients over this time period in most science fields except in mathematical and social sciences. The increment is most pronounced in physical sciences and engineering. At the same time, the total number of bachelor's degree recipients in physical sciences and engineering has actually declined over this time period. Thus, the increase in the proportion of women is partly due to the recent decrease of men in these fields.

Nevertheless, the distribution pattern of women graduates over the fields has not changed markedly since the fifties. Women are much more likely to receive their degrees in psychology, social sciences and mathematics than in physical sciences and engineering, as compared to men. The pattern for master's degree recipients is similar to that for the bachelor's, except for the fact that the proportion of women receiving master's degrees is in general smaller. The only exception to this generalization is engineering. Women constitute a slightly higher proportion of master's degree recipients in engineering than that of bachelor's, 0.7% versus 0.5%. More detailed data by field and year on percentages of women awarded bachelor's and master's degrees are shown in Tables 3.2 and

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[2] In addition to the sources of data already cited, the following source has proved useful. B.M. Vetter and E.L. Babco, Professional Women and Minorities: A Manpower Resource Service, Scientific Manpower Commission, Washington, D.C. 1975.

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3.3, respectively.

In Tables 3.4 and 3.5, data on doctoral degree recipients are displayed. From 1920 to 1973 about 25,000 doctorates were awarded to women in science and engineering, about 9% of all the doctorates in these fields. Notably, the distribution of women doctorates over the fields is similar to, but not the same, as that for degrees. Again, the largest proportion of women is in psychology (22%), next come life and social scientists (12% and 10%), followed by mathematicians (7%), physical scientists (5%), and engineers (10.%). As was pointed out before, the proportion of women bachelor's degree recipients who receive a doctorate is unusually low in the mathematical sciences.

There are significant variations in the representation of women in fields within these broad field categories. Thus, within life sciences, women are best represented in biological (16%) and medical (11%) sciences,but are very scarce in agriculture science (2%). Within social sciences, women are relatively well represented in anthropology (23%) and sociology (18%),but their proportion in political science and public administration (9%) and in economics (5.5%) is much smaller. Within physical sciences more women are to be found among chemists (6%) than among physicists, astronomers, and earth scientists (3%).

Table 3.5 and Figure 3.1 show trends in doctoral degrees awarded to women as a function of time. The change in percentages with time is very similar in all fields. There was a steady decrease in the percentage of total doctorates which were awarded to women from 1920 to 1950, which reached a low point in the fifties. From the 1950's on, the percentages increase significantly, with the sharpest increase occurring most recently.

However, the distribution of women doctorates over different fields with the sciences remains approximately constant. This is illustrated in Figure 3.2. In this figure is plotted the percentage ratio of doctoral degrees awarded to women by field and decade. This percentage ratio is computed by dividing the percentage of degrees awarded to women in a given field by the percentage of degrees awarded to women in all fields (science and non-science). If women were distributed over the fields in the same proportions as men, the percentage ratio would be equal to one for every field. As we can see from this figure, the percentage ratio is close to one for life sciences, it is slightly greater than one for social sciences and psychology, it varies between about 0.4 and 0.5 for physical sciences and mathematics, and it is less than 0.1 for engineering. For all sciences and engineering combined the percentage ratio varies between about 0.6 and 0.8 over the years. The next feature to be observed from Figure 3.2 is that the percentage ratios in all fields changed only slightly with time. This indicates that despite the recent marked increase in women doctorate recipients that the science professions continue to exhibit vocational sex segregation. Compared to other fields, women doctorates continue to be greatly under-represented in physical and mathematical sciences and in engineering.

There is evidence that for women doctorates there is a much greater preselection with respect to academic credentials and ability. This is illustrated in Figure 3.3. This figure, reproduced from a study by Harmon[3], compares high school performance profiles of social scientists, bio-scientists and chemists by sex and marital status at doctorate. The performance is based on grade point averages in four fields, rank in graduating class, and a standardized ability test score. In every performance category, women score higher than men for each of the three fields. Comparing by field, for both sexes chemists show consistently higher scores than social scientists; this difference is most pronounced in mathematics and science scores. Yet, the science and mathematics scores of women social scientists are comparable to male chemists. Thus, the Harmon study suggests that many other factors besides ability influence the choice of specialty for women doctorates.[4,5]

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[3] Harmon, Lindsey R., "High School Ability Patterns," Scientific Manpower Report No. 6, National Research Council, National Academy of Science, Washington, D.C., 1965. See also Vera Kistiakowsky, "Women in Engineering, Medicine and Science, a Demographic Paper," National Academy of Sciences, Washington, D.C., 1973.

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[4] Additional evidence that women doctorates enter graduate school with exceptionally strong academic and intellectual credentials can be found in Jonathan R. Cole, Women's Place in the Scientific Community, New York, forthcoming; and J.A.Creager, The American Graduate Student: A Normative Description, American Council on Education Research Reports, 6 (5), Washington, D.C., 1975. Cole studied matched samples of women and men who received doctorates in physics, mathematics, chemistry, biology, psychology and sociology. This study shows that in each of the five fields and at every level of prestige of university graduate departments, women had consistently higher intelligence scores than men. (This study is briefly described in: Harriet Zuckerman and Jonathan R. Cole, "Women in American Science," Minerva, A Review of Science, Learning and Policy, 13 (1), Spring, 1975). Creager finds that 50.9% of women graduate students have an undergraduate grade point average of B+ or higher compared to 39.5% for men.

[5] "Women in Political Science, Studies and Reports on the Status of Women in the Profession, 1969-71," American Political Science Association, Washington, D.C., 1971. This publication describes a survey of a sample of graduate students in political science which shows that 51% of women and 32% of men graduate students received past academic honors. (The survey sample consisted of 635 women and a control sample of 94 men.)

On the average, women take slightly longer than men in obtaining the doctorate. This is illustrated in Tables 3.6 and 3.7 and in Figures 3.4 and 3.5. Table 3.6 shows the median time lapse between B.A. and Ph.D. for doctoral scientists and engineers by sex and field.[6] This time lapse is 8 years for women and 6.6 years for men for all science and engineering fields. There is considerable variation by field for both men and women. The time interval between B.A. and Ph.D. is the longest in the social sciences, 9.8 years for women and 8.5 years for men. It is the shortest in the physical sciences, 5.7 years for men and 6.3 years for women.[7] The time lapse difference between men and women is 0.5 years in physical science, the least in all fields. Thus, the fact that women take about 1.4 years longer than men to obtain their doctorate is partly accounted for by their larger representation in fields in which doctorate training is longer.

Another reason for the longer time lapse between B.A. and Ph.D. for women doctorates is evident from Figure 3.4. This figure shows the dictribution in time lapse between B.A. and Ph.D. by sex for four broad field categories. This figure clearly shows a greater tendency for women to obtain their degrees in later years. From these figures, it is apparent that in the physical and mathematical sciences and, to a lesser extent, in life science, the distributions are very similar for both sexes up to a time lapse of about fifteen years. A much higher fraction of women than men take sixteen years or longer for the doctorate. In psychology and social science a significantly larger fraction of men than women take less than 8 years to obtain their doctorate; correspondingly, a much larger proportion of women than men take 16 years or longer. This pattern suggests than unlike most men, many women return to graduate school in later years when they choose fields like psychology and social science in preference to the natural sciences.

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[6] Table 3.6 and Figures 3.4 and 3.5 were prepared from unpublished data of the NAS-NRC survey of doctoral scientists. (cited in footnote 2, Section 2.)

[7] "Report to the Council of the AAS from the Working Group on the Status of Women in Astronomy, 1973," Bulletin, American Astronomical Society, 6 (3), part II, 1974. A survey by the American Astronomical Society of its membership showed that women are slightly younger than men on receiving the doctorate. For women, the median age at Ph.D. is 26, for men it is 27. The average number of years enrolled in graduate school is 5.2 for women and 4.8 for men.

Figure 3.5 shows the median time lapse between B.A. and Ph.D. for men and women as a function of time when Ph.D. was received. The time lapse difference between sexes decreases from early to later years. In the 1930's and early forties, women took two years longer than men to obtain their doctorate; from the 1960's on, the time difference between sexes has been reduced to about one year.

The age at receipt of the doctorate and the time lapse between receipt of bachelor's and doctoral degrees has also been studied by Centra.[8] The data from the Centra study are presented in Table 3.7. His results show trends similar to those from the NAS-NRC survey discussed previously. The average age at completion of the doctorate and the time lapse between the B.A. and the Ph.D. are higher for women than for men, they are highest in social sciences and lowest in physical sciences for both sexes. Centra also finds that it is more typical for women than for men to obtain their degrees later in life. However, the actual numbers from the Centra data differ considerably from the NRC survey numbers, as can be seen by comparing Table 3.7 with Table 3.6 and Figure 3.4.[9]

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[8] Centra, John A. Women, Men and the Doctorate. Educational Testing Service, Princeton, Jew Jersey, 1974. Centra surveyed a sample of doctoral recipients from three time periods: 1950, 1960 and 1968. From the original randomly selected sample of women, about 1,800 were surveyed in all science and non-science fields. A male sample of about the same size matched on year, field and institution was selected for comparison.

The data on financial support of graduate students do not show great differences between men and women. Table 3.8 shows data from the National Science Foundation survey of graduate departments on financial support of graduate students in physical and mathematical sciences in 1972-73.[7] This table shows women to be slightly less likely than men to receive financial support in these fields. Men are more likely to be supported by the government funds, while women are more likely to receive non-government support. A 1974 survey of 57 universities by the American Economics Association [10] found very little difference in the extent of financial support of male and female students in economics. These data are shown in Table 3.9. Similar results were found in sociology.[11] A survey of graduate sociology departments showed that women students received financial support at about the same rate as men: 37% of those admitted to graduate school were women and 37.5% of financial support recipients were women. A survey of women graduate students in political science[5] shows 46% of women and 50% of men receiving financial support. Table 3.10 shows doctoral recipients by sources of support in graduate school. The numbers given are totals for all science and non-science fields. The data in this table indicate that women use personal funds to support their education in graduate school to a greater extent than men.

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[9] The differences in the two sets of data probably arise from differences in sampling procedures and field definitions.

[10] Annual Report, American Economic Association Committee on the Status of Women in the Economic Profession, 1974.

[11] The Status of Women in Sociology, 1968-72, Report to the American Sociological Association of the Ad Hoc Committee on the Status of Women in the Profession, ASA, Washington, D.C., 1973.

Table 3.1

DEGREES AWARDED BY SEX, BROAD FIELD CATEGORY AND YEAR

DEGREE AND YEAR	Physical Sciences (Chem., Phys., Astro., Geosc.)			Mathematical Sciences (Comp.Sc.[1], Math.[2], Stat.[3])			Engineering			Life Sciences (Biochm., Biolog.Sc.[4], Agric.Sc.[5])			Psychology			Social Sciences (Anthrop., Socio., Econom.[6], Pol. Sc.)			All Science Fields		
	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %
Bachelors																					
1947-48 thru 1959-60	159,878	20,506	12.8	76,278	22,200	29.1	435,534	1,356	0.3	254,757	43,081	16.9	89,724	38,479	42.9	276,218	75,104	27.2	1,292,389	200,726	15.5
1960-61 thru 1969-70	166,383	23,005	13.8	205,371	69,046	33.6	372,020	1,880	0.5	317,428	75,280	23.7	181,611	75,916	41.8	461,657	150,355	32.6	1,704,470	395,482	23.2
1970-71	19,691	2,825	14.3	26,542	9,730	36.7	45,209	361	0.8	46,863	11,069	23.6	38,469	17,151	44.6	82,821	29,879	36.1	259,595	71,015	27.4
1971-72*	19,224	2,889	15.0	27,115	9,720	35.8	45,392	480	1.0	48,753	11,658	23.9	43,093	19,934	46.3	83,733	29,849	35.6	267,310	74,530	27.9
1972-73*	18,034	2,737	15.2	26,363	9,626	36.5	44,118	543	1.2	52,496	12,946	24.7	45,643	21,672	47.4	82,612	29,520	35.7	269,266	77,044	28.6
Total	383,210	51,962	13.6	361,669	120,322	33.3	942,273	4,620	0.5	720,297	154,034	21.4	398,540	173,152	43.4	987,041	314,707	31.9	3,793,030	818,797	21.6
Masters																					
1947-48 thru 1959-60	34,303	2,825	8.2	12,989	2,526	19.4	63,909	219	0.3	41,702	6,088	14.6	16,669	5,072	30.4	24,527	4,438	18.1	199,099	21,168	10.9
1960-61 thru 1969-70	44,053	4,700	10.7	46,804	10,190	21.8	123,075	716	0.6	56,421	12,669	22.5	27,052	9,063	33.5	41,925	8,604	20.5	339,330	45,942	13.5
1970-71	5,631	764	13.6	6,789	1,688	24.9	16,323	185	1.1	8,174	2,177	26.6	4,438	1,651	37.2	6,890	1,755	25.5	48,245	8,220	17.0
1971-72*	5,665	820	14.5	7,175	1,768	24.6	16,723	271	1.6	8,390	2,177	25.9	5,289	2,030	38.4	7,437	1,902	25.6	50,679	8,968	17.7
1972-73*	5,125	740	14.4	6,690	1,694	25.3	15,192	247	1.6	8,221	1,975	24.0	5,668	2,264	39.9	7,049	1,796	25.5	47,945	8,716	18.2
Total	94,777	9,849	10.4	80,447	17,866	22.2	235,222	1,638	0.7	122,908	25,086	20.4	59,116	20,080	34.0	87,828	18,495	21.1	680,298	93,014	13.7

* Preliminary Data.

[1] Not identified as separate field until 1964-65.

[2] Includes statistics until 1955-56.

[3] Data begins for 1955-56 when identified as separate field.

[4] Does not include biochemistry or biophysics.

[5] Does not include forestry.

[6] Does not include agricultural economics.

Source: B.M. Vetter and E.L. Babco, "Professional Women and Minorities, A Manpower Resource Service", Scientific Manpower Commission, Washington, D.C. May 1975; original source: " Earned Degrees Conferred", U.S. Dept. of Health, Education and Welfare, Washington, D.C.

Table [illegible].2

BACHELOR'S DEGREES AWARDED BY SEX AND FIELD

	Total No. Both Sexes	No. of Women	% of Women	1947-60	1960-70	1970-71	1971-72*	1972-73*
Chemistry	224,366	42,325	18.9	18.6	19.0	18.7	19.4	19.1
Biochemistry	6,378	1,421	22.2	14.4	26.8	24.3	25.0	23.7
Physics	98,567	5,154	5.2	4.5	5.3	6.8	6.9	7.4
Astronomy	1,467	229	15.6	21.0	13.9	7.8	16.5	21.2
Geology and Earth Science	58,810	4,254	7.2	4.1	9.1	11.4	12.7	13.2
Computer Sc.[1]	12,488	1,729	13.8	-	12.5	14.5	13.5	14.9
Mathematics[2]	345,899	117,967	34.1	29.1	34.2	38.2	39.1	40.6
Statistics[3]	3,282	626	19.0	22.7	16.0	25.3	27.9	34.8
Engineering	942,273	4,620	0.5	0.3	0.5	0.8	1.0	1.2
Biological Sc.[4]	559,302	146,828	26.2	25.8	28.4	29.4	29.5	30.0
Agricultural Sc.[5]	187,356	5,917	3.1	1.8	3.4	4.8	6.9	7.5
Psychology	398,540	173,152	43.4	42.9	41.8	44.6	46.3	47.4
Anthropology	34,856	18,541	53.2	47.3	53.7	55.5	54.3	53.0
Sociology	349,671	203,763	58.3	57.0	59.6	59.3	56.7	55.8
Economics[6]	288,882	28,929	10.0	9.8	9.5	11.2	11.7	13.7
Political Sc.	313,628	63,474	20.2	18.6	21.5	20.1	18.8	19.2

* Preliminary data.

[1] Not identified as separate field until 1964-65.
[2] Includes statistics until 1955-56.
[3] Data begins for 1955-56 when identified as separate field.
[4] Does not include biochemistry or biophysics.
[5] Does not include forestry.
[6] Does not include agricultural economics.

Source: B.M. Vetter and E. L. Babco, "Professional Women and Minorities, A Manpower Resource Service", Scientific Manpower Commission, Washington, D.C. May 1975; original source: "Earned Degrees Conferred", U.S. Dept. of Health, Education, and Welfare, Washington, D.C.

Tabl[illegible].3

MASTER'S DEGREES AWARDED BY SEX AND FIELD

	Total Number Both Sexes	Number of Women	% of Women	Percent of Women				
				1947-60	1960-70	1970-71	1971-72*	1972-73*
Chemistry	40,245	6,827	17.0	13	18.9	21.6	22.3	21.1
Biochemistry	4,720	1,334	28.3	22.1	30.6	39.4	35.7	28.2
Physics	35,290	1,727	4.9	3.9	4.7	6.9	7.8	6.5
Astronomy	1,129	139	12.3	12.7	12.1	12.0	12.3	13.1
Geology and Earth Science	18,113	1,156	6.4	3.5	6.4	10.4	11.5	13.4
Computer Science[1]	9,334	893	9.6	-	7.5	10.3	11.4	11.3
Mathematics[2]	65,787	16,129	24.5	19.8	23.8	30.3	30.5	31.7
Statistics[3]	5,326	844	15.8	11.1	14.6	20.0	20.4	22.6
Engineering	235,222	1,638	0.7	0.3	0.6	1.1	1.6	1.6
Biological Sc.[4]	84,434	22,452	26.5	21.0	27.7	33.8	32.4	30.5
Agricultural Sc.[5]	33,921	1,323	3.9	1.9	4.5	6.2	7.4	7.5
Psychology	59,116	20,080	34.0	30.4	33.5	37.2	38.4	39.9
Anthropology	6,506	2,494	38.3	31.0	36.9	44.0	44.4	42.5
Sociology	21,750	7,237	33.3	30.6	31.8	37.4	38.7	40.5
Economics[6]	29,997	3,319	11.1	10.8	10.5	13.1	12.8	12.4
Political Sc.	29,575	5,445	18.4	15.2	19.2	21.4	20.5	20.1

* Preliminary data.

[1] Not identified as separate field until 1964-65.
[2] Includes statistics until 1955-56.
[3] Data begins for 1955-56 when identified as separate field.
[4] Does not include biochemistry or biophysics.
[5] Does not include forestry.
[6] Does not include agricultural economics.

Source: B.M. Vetter abd E.L. Babco, "Professional Women and Minorities: A Manpower Resource Service", Scientific Manpower Commission, Washington, D.C., 1975; origonal Source: "Earned Degrees Conferred", US Department of Health, Education and Welfare, Washington, D.C.

Table 3.4

DOCTORAL DEGREES BY SEX AND FIELD, 1920-73

	1920-1972			1973		
	Total No.	Women No.	Women %	Total No.	Women No.	Women %
Chemistry	42,190	2,550	6.0	1,849	179	9.7
Biochemistry	9,600	1,519	15.8	636	129	20.3
Physics	21,910	490	2.2	1,459	50	3.4
Astronomy	1,094	108	9.9	64	4	6.2
Geology and Earth Science	8,341	221	2.6	577	22	3.8
Computer Sc.[1]	564	21	3.7	174	15	8.6
Mathematics	14,353	1,001	6.7	1,222	119	9.7
Statistics[2]	1,320	89	6.7	-	-	-
Engineering	37,709	164	0.4	3,338	45	1.3
Biological Sc.[3]	38,522	5,840	15.2	2,743	590	21.5
Agricul. Sc.	12,661	226	1.8	953	37	3.9
Health Sc.	6,948	717	10.3	573	108	18.8
Psychology	26,383	5,530	21.0	2,444	716	29.3
Soc. Sc. (Total)	37,197	3,754	10.1	3,467	527	15.2
Anthropology	2,503	563	22.5	324	96	29.6
Sociology	7,045	1,227	17.4	599	154	25.7
Economics	13,638	738	5.4	907	57	6.3
Pol.Sc./ Pub.Adm.	8,147	683	8.4	780	93	11.9
Soc. Sc. Other	5,864	54[illegible]	9.2	857	127	14.8
Total	258,792	22,230	8.6	19,499	2,541	13.0

[1] No degree prior to 1964.

[2] No degree prior to 1954 or past 1971.

[3] Excluding biochemistry.

Source: B. M. Vetter and E. L. Babco, "Professional Women and Minorities, A Manpower Resource Service", Scientific Manpower Commission, Washington, D.C., May 1975, original source: Doctorate Records File, National Research Council, National Academy of Sciences, Washington, D.C.

Table 3.5

NUMBER AND PERCENT OF DOCTORAL DEGREES GRANTED TO WOMEN, BY FIELD AND DECADE 1920- 1973

	DECADE																	
	1920-29		1930-39		1940-49		1950-59		1960-69		1970-72		1973		1970-73		1920-73 TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
PHYSICAL SCIENCES	196	6.8	327	5.5	317	4.3	572	3.5	1,213	4.3	758	5.7	255	6.5	1,013	5.9	3,638	4.7
Physics & Astron.	39	5.9	51	3.8	62	4.2	98	2.0	213	2.2	135	2.8	54	3.5	203	3.1	666	2.7
Chemistry	141	7.3	254	6.4	223	4.2	443	4.4	931	6.4	558	8.7	179	9.7	737	8.9	2,729	6.2
Earth Sciences	16	4.8	22	3.5	32	5.7	31	1.9	69	2.0	51	3.1	22	3.8	73	3.3	243	2.7
MATHEMATICS	51	14.5	115	14.8	89	10.7	113	5.0	364	5.7	281	7.2	119	9.7	388	7.8	1,120	7.0
ENGINEERING	2	0.9	6	0.7	7	0.5	20	0.3	77	0.4	52	0.5	45	1.3	97	0.7	209	0.5
LIFE SCIENCES	378	15.9	765	15.1	738	12.7	1,318	9.1	3,078	11.6	2,026	14.1	864	17.6	2,904	14.8	9,181	12.4
Biological	341	19.5	698	17.8	699	15.7	1,174	11.8	2,739	15.1	1,708	17.3	719	21.3	2,427	18.3	8,078	15.7
Agricultural	8	2.2	11	1.6	5	0.6	36	1.1	80	1.4	87	3.1	37	3.9	124	3.1	264	1.8
Medical	29	10.9	56	12.4	34	6.9	108	8.1	259	9.5	231	13.8	108	18.8	339	15.1	825	11.0
SOCIAL SCIENCES	136	10.8	272	11.1	278	10.1	599	7.9	1,340	9.4	1,129	12.4	527	15.2	1,656	13.2	4,281	10.5
Anthropology	8	22.2	28	22.4	22	15.2	90	19.3	218	21.5	197	27.4	96	29.6	293	28.1	659	23.3
Sociology	32	15.4	89	19.9	99	17.2	221	14.2	442	17.5	344	19.9	154	25.7	498	21.4	1,381	18.1
Economics	52	8.5	71	6.4	83	7.1	125	4.2	245	4.6	162	6.6	57	6.3	219	6.5	795	5.5
Pol. Sc. & Pub.Adm.	26	9.0	45	8.5	45	7.8	87	5.4	257	8.2	223	11.1	93	11.9	316	11.3	776	8.7
PSYCHOLOGY	189	29.4	290	26.0	302	24.1	911	14.8	2,264	20.7	1,574	25.1	716	29.3	2,290	26.3	6,246	21.7
ALL SCIENCES	952	12.3	1,775	11.0	1,731	9.0	3,533	6.6	8,336	7.9	5,807	10.2	2,541	13.0	8,348	10.9	24,675	8.8
NON-SCIENCE FIELDS	866	21.1	1,984	21.1	2,381	21.4	4,438	16.1	10,588	18.7	-	-	-	-	11,503	22.7	31,760	19.9
TOTAL ALL FIELDS	1,826	15.3	3,784	14.8	4,115	13.5	7,972	9.9	18,964	11.7	-	-	-	-	19,916	15.6	56,577	12.9

Source: B. M. Vetter and E. L. Babco, "Professional Women and Minorities, A Manpower Resource Service," Scientific Manpower Commission, Washington, D.C., 1975; original source: Docterate Records File, National Research Council, National Academy of Sciences, Washington, D.C.

Table 3.6

MEDIAN TIME LAPSE BETWEEN B.A. AND PH.D. FOR DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND FIELD

Field	Time Lapse in Years men	 women
Total Science and Engineering	6.6	8.0
Physical Science	5.7	6.3
Chemistry	5.3	6.2
Physics/Astronomy	6.4	6.8
Mathematical Science	6.2	7.4
Mathematics	6.1	7.4
Statistics	7.4	8.5
Computer Specialists	6.8	-
Enviromental Science	7.3	7.3
Earth Science	7.2	7.4
Oceanography	7.6	-
Atmospheric Science	8.2	-
Other	-	-
Engineering	7.0	7.8
Life Science	6.7	7.7
Biological Science	6.5	7.6
Agricultural Science	7.1	8.8
Medical Science	7.6	9.4
Psychology	6.6	8.3
Social Science	8.5	9.8
Economics	8.5	9.6
Sociology/Anthropology	9.0	9.8
Other	8.3	9.7
Non-Science	11.0	15.7

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

Table 3.7

AGE AT DOCTORATE AND TIME LAPSE BETWEEN B.A. AND Ph.D.

FOR MEN AND WOMEN DOCTORATES

Field	Time Lapse B.A. to Ph.D. in years		Average Age at Doctorate in years		Percent of Each Sex Receiving Degrees after Age 37	
	Men	Women	Men	Women	Men	Women
Social Science[1] and Psychology	9.9	13	31	35	21%	39%
Biological Science	8.1	9.9	31	32	10%	25%
Physical Science[2]	7.0	8.1	29	30	5%	12%

[1] Includes History and Geography

[2] Includes Mathematics, Engineering and Enviromental Science

Source: John A. Centra, "Women, Men and Doctorate", Educational Testing Service, Princeton, New Jersey, September 1974 (from data on pp. 23 and 24).

Table 3.8

FINANCIAL SUPPORT OF GRADUATE STUDENTS IN PHYSICAL SCIENCES, 1972-73

				Percent of Each Sex with Support over $1,200					
		No. of Full-time Students		US Gov't Support		Non-Gov't Support		Total Support	
Department	No. of Departments	men	women	men	women	men	women	men	women
Physics	220	8,822	571	39.0	27.7	51.5	59.9	90.5	87.6
Chemistry	216	10,092	1,842	30.7	25.3	63.4	67.3	94.1	92.6
Physical Sc.	683	25,787	3,161	35.0	26.6	54.3	61.7	89.3	88.3
Math. Sc.	320	10,595	2,383	16.5	11.2	59.6	62.1	76.1	73.3

Source: "Report to the Council of AAS from the Working Group in Astronomy, 1973", Bulletin, American Astronomical Society, 6 (3), part II, 1974; original source: NSF Survey of Graduate Departments, 1972-73.

Table 3.9

FINANCIAL SUPPORT OF STUDENTS IN ECONOMICS, 1974

Full-time Students	Senior Majors	Ph.D. Candidates	M.A. Candidates	Scholarships	Fellowships	Assistantships
Total Number	9,423	4,379	2,724	563	1,009	2,294
Women as % of Total	15%	12%	14%	17%	16%	15%

Source: Annual Report, American Economic Association, Committee on the Status of Women in the Economic Profession, 1974.

Table 3.10

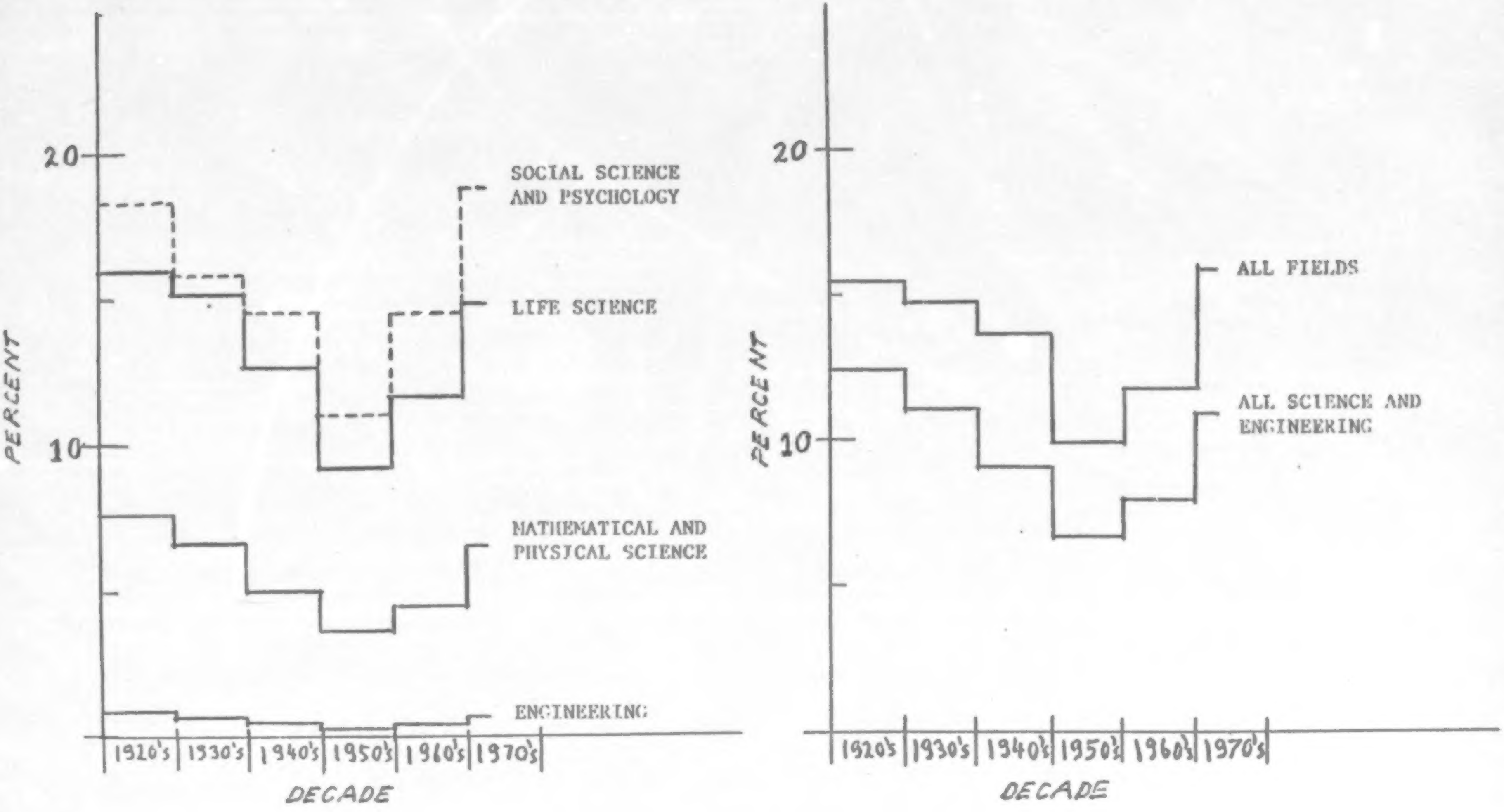
NUMBER OF DOCTORATE RECIPIENTS BY SOURCES OF SUPPORT IN GRADUATE SCHOOL, FISCAL 1972

	Number		% of	% of
Source of Support	Men	Women	Men	Women
Federal Support				
NSF Fellowship	1,519	225	5.8	4.6
NSF Traineeship	1,557	129	5.9	2.6
NIH Fellowship	919	293	3.5	5.9
NIH Traineeship	1,366	418	5.2	8.5
NDEA Fellowship	3,418	652	13.0	13.2
AEC Fellowship	183	5	0.7	0.1
NASA Traineeship	622	39	2.4	0.8
GI Bill	2,832	32	10.8	0.6
Other	2,614	525	10.0	10.6
National Fellowships				
Woodrow Wilson Fellowship	521	174	2.0	3.5
Other	768	205	2.9	4.2
Institutional Funds				
University Fellowship	4,964	1,083	18.9	22.0
Teaching Assistantship	12,768	2,151	48.6	43.6
Research Assistantship	9,688	1,097	36.9	22.2
Educational Funds of Industry	1,092	101	4.2	2.0
Other	2,591	650	9.9	13.2
Personal Funds				
Own Earnings	9,733	2,079	37.1	42.2
Spouse's Earnings	5,134	1,041	19.6	21.1
Family Contribution	1,682	411	6.4	8.3
Borrowings	3,339	522	12.7	10.6
Other	1,519	358	5.8	7.3
Unduplicated Total	26,248	4,932		

Source: B.M. Vetter and E.L. Babco, "Professional Women and Minorities, a Manpower Resource Service", Scientific Manpower Commission, Washington, D.C. 1975 (table G-D-9 on p.57); original source: "Summary Report 1972, Doctoral Recipients from the United States Universities", National Research Council, 1973.

Figure 3.1

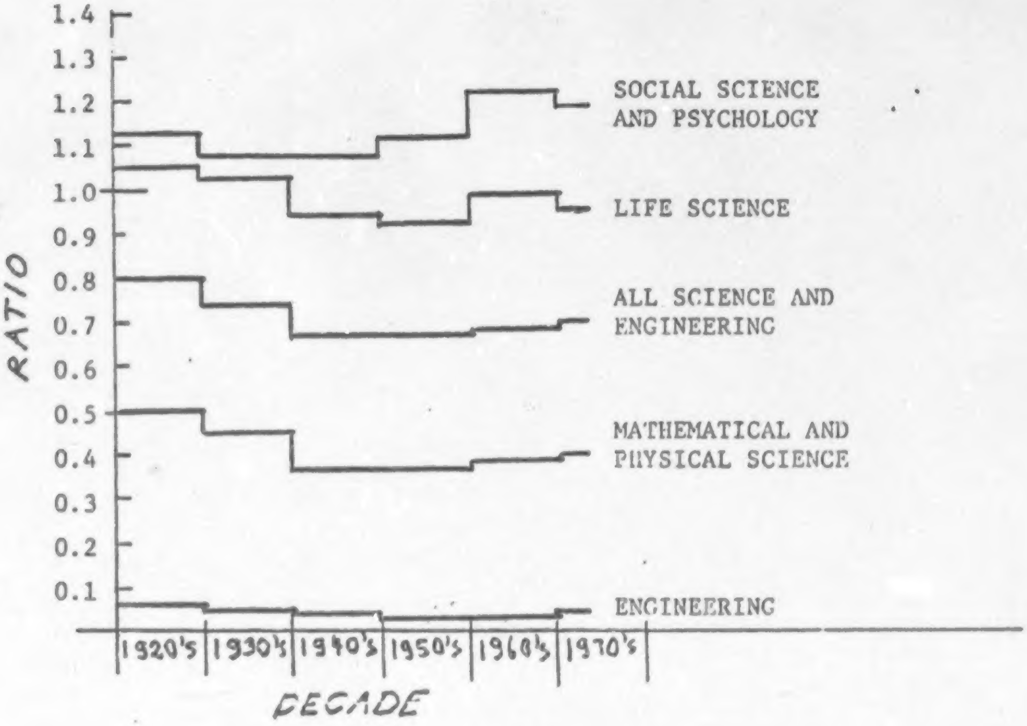
PERCENTAGE OF PH.D. DEGREES RECEIVED BY WOMEN BY FIELD AND DECADE



Source: Doctoral Record File, National Research Council, National Academy of Sciences, Washington, D.C.

Figure 3.2

PERCENTAGE RATIO* OF DOCTORAL DEGREES AWARDED TO WOMEN BY FIELD AND DECADE

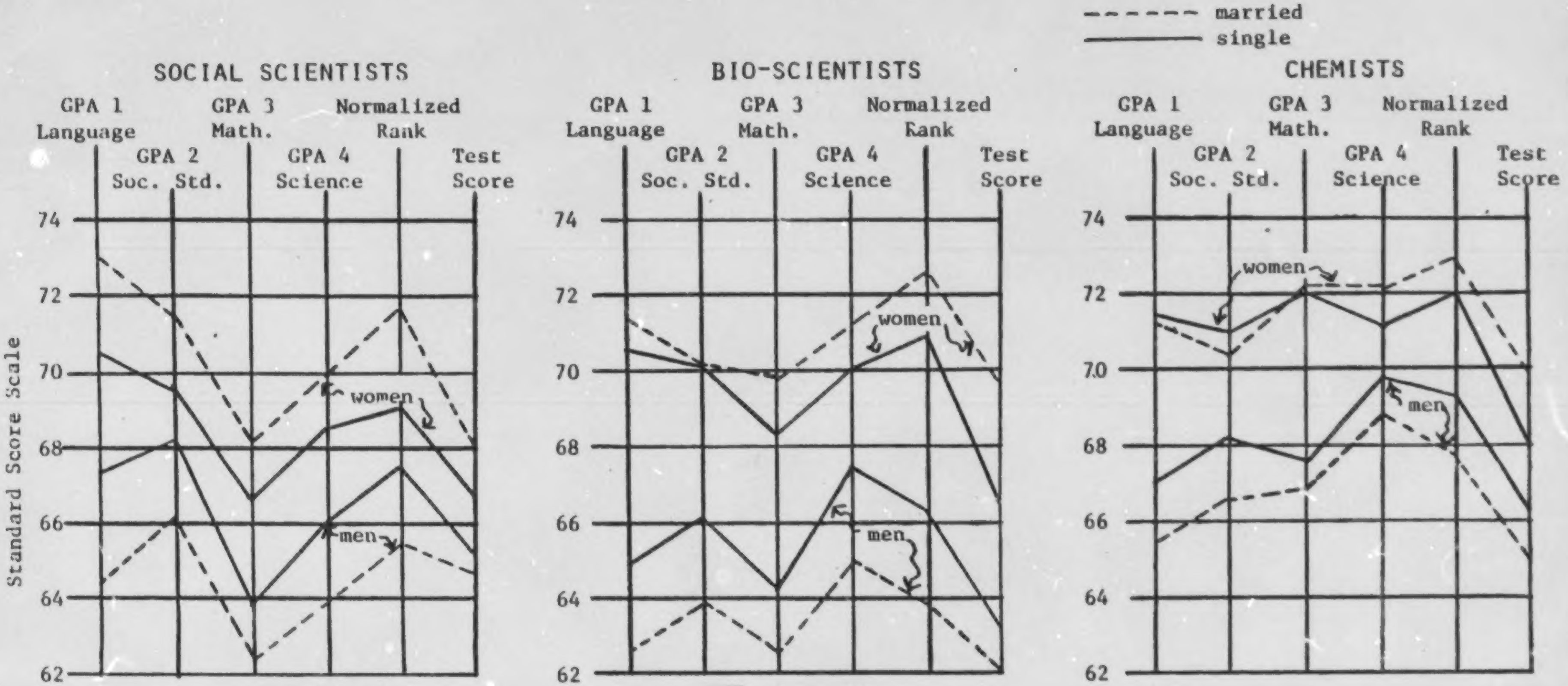


*Percentage ratio is obtained by dividing the percentage of degrees in a given field by the percentage of degrees in all fields

Source: Doctoral Record File, National Research Council, National Academy of Sciences, Washington, D.C.

Figure

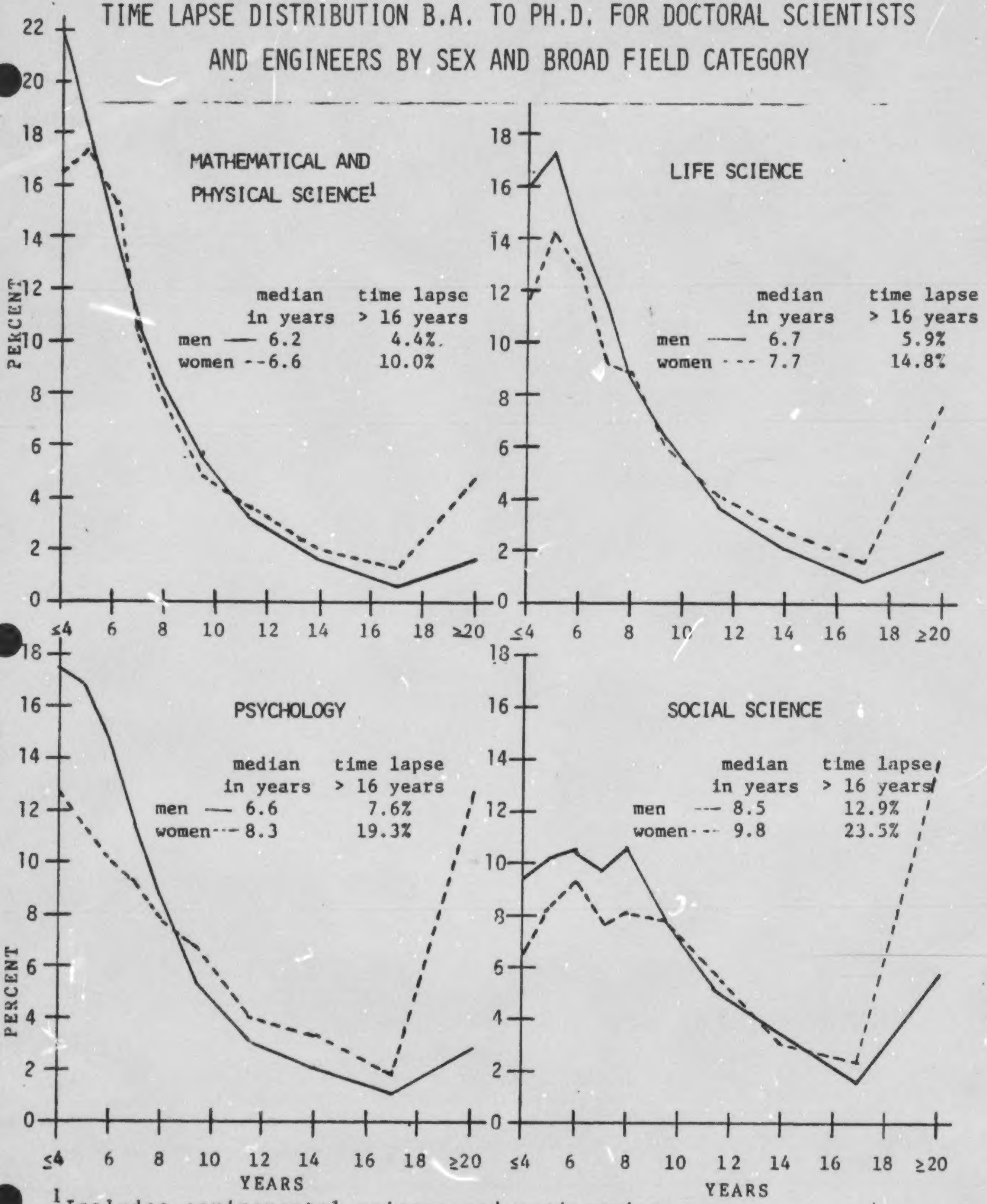
PROFILE OF SCIENTISTS, BY SEX AND MARITAL STATUS AT DOCTORATE, ON SIX HIGH SCHOOL VARIABLES.



Source: Lindsey R. Harmon, "Highschool Ability Patterns", Scientific Manpower Report No. 6, National Research Council, National Academy of Sciences, Washington, D.C. 1965.

Figure 3.4

TIME LAPSE DISTRIBUTION B.A. TO PH.D. FOR DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND BROAD FIELD CATEGORY

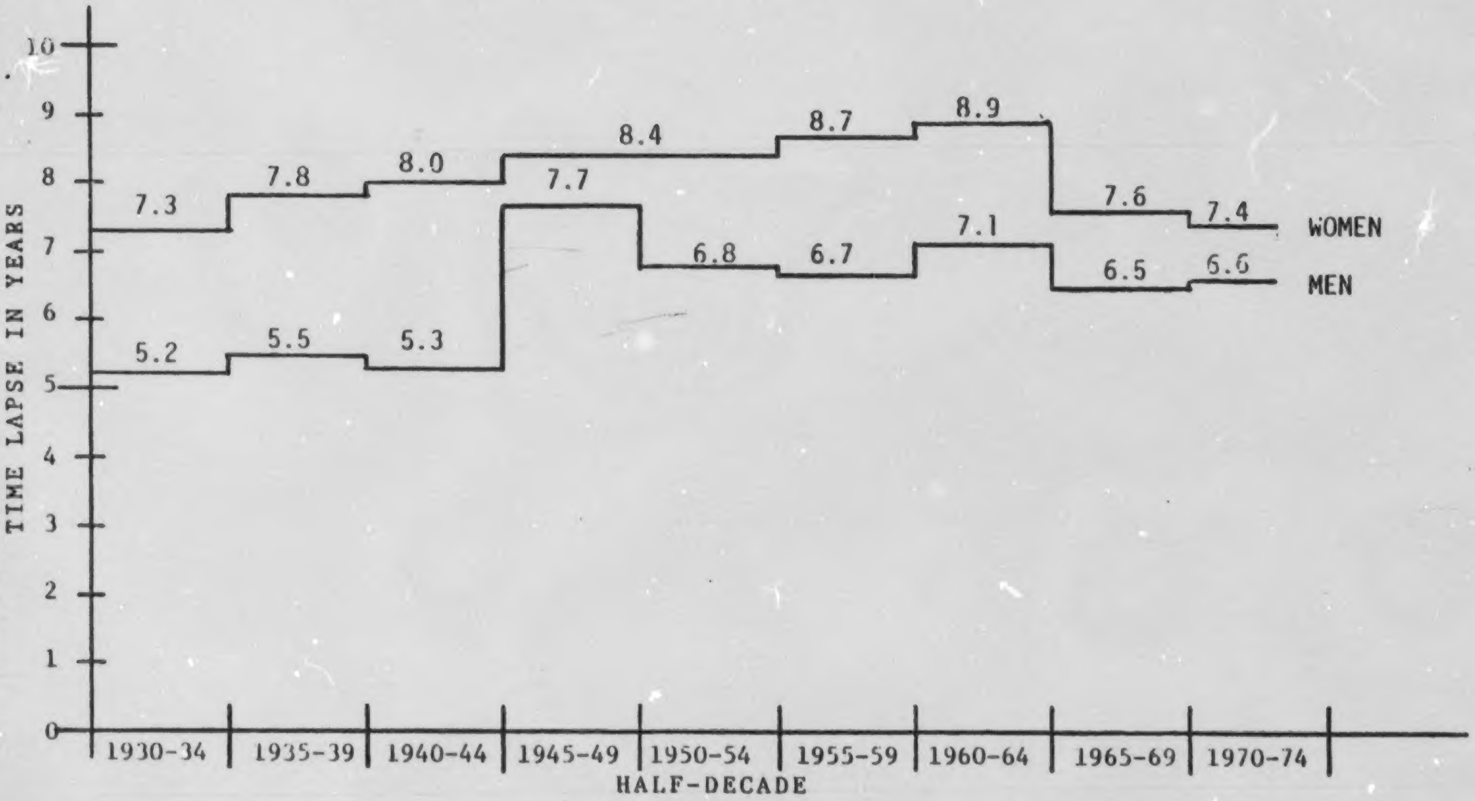


[1] Includes enviromental science and engineering.

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

Figure 3.5

MEDIAN TIME LAPSE B.A. TO PH.D. FOR DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND YEAR OF PH.D. RECEIPT



Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

SECTION 4

The Extent of Participation in the Scientific Work Force

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In this section, the extent to which women and men educated in science and engineering participate in the scientific work force is discussed. Unemployment and underemployment rates of men and women scientists are analyzed and compared. Field switching is examined and compared by sex. In this way, a clearer pattern of the way men and women function professionally in the sciences can be discerned.

In the previous section, the fact that 22% of bachelor's degrees in science were awarded to women was set forth. This represents the proportion of women with bachelor's or higher degrees educated in scientific and engineering fields since 1948. At the same time, according to the 1972 postcensal survey[1] only 6% of all scientists and engineers are women. Why is there such a large discrepancy between the proportion of women educated in science and engineering and those working in these fields? In an attempt to answer this question, an analysis of the labor force participation of college-educated men and women is a good place to start. Table 4.1 presents 1971 census data on persons with four or more years of college education (in all science and non-science fields) by sex and race. The table shows that 88% of college-educated men and 65% of women are in the employed labor force, i.e., working for income. However, by assuming that men and women educated in science and engineering are represented in the scientific labor force in the same proportions as in the total college-educated population the percentage for women would be 17% of all scientists and engineers.[2] The actual percentage of women scientists is about a third of this expectation. One way to account for this figure is to acknowledge the possible factors taken together or singly which suggest: a) a much larger proportion of women than men educated in science wind up working in a non-science field and b) a high degree of underemployment exists among women educated as scientists and engineers.[3]

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[1] Demographic, Educational and Professional Characteristics, The 1972 Scientist and Engineer Population Redefined, Volume 1, NSF 75-313, Washington, D.C.

Table 4.2 presents the comparison of the labor force participation of men

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[2] More precisely, letting M and W be the numbers of men and women respectively educated in science, and using the numbers in Table 4.1, the expected fraction of women working in science is $X = .653W/(.653W + .879M)$. Using the values from Table 3.1, $M = 3{,}793{,}030$ and $W = 818{,}737$, we get $X = .170$.

[3] So far as is known, no comprehensive study designed to assess the degree of underemployment among women scientists and engineers below the doctorate level has been made. Underemployment of doctoral scientists and engineers is discussed later in this section. However, an independent survey of women in atmospheric science (Joanne Simpson and Margaret LeMore, "Women in Meteorology," Unpublished Report, 1973) shows that out of 65 atmospheric scientists with master's degrees, 9 left the field altogether through lack of opportunity, while at least a half-dozen of about 80 bachelor's degree-holders were working in subprofessional jobs. Also, a report on Professionals in Chemistry (P.A. Benetatos, "Professionals in Chemistry, 1974," Office of Manpower Studies, American Chemical Society, Washington, D.C., March, 1975, p. 11) shows that among chemists with bachelor's degrees women stayed out or left the chemical labor force at a higher rate than men.

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and women doctorate scientists and engineers.[4] Labor force includes all full-time and part-time employed scientists and engineers as well as all unemployed and seeking employment. As can be seen, 94.5% of men and 84.9% of women are in the labor force. Labor force participation varies somewhat by field for both men and women; however, in each field, a larger fraction of men than women are in the labor force. In social sciences, including psychology, more women, 88.1% and fewer men, 93.2%, are in the labor force in comparison with other fields. However, in natural sciences, it is the other way around: slightly more men, 95.1%, and fewer women, 83.2%, participate in the labor force.

Some of the differences in the labor force participation between men and women can be accounted for by the age distribution differences between the two sexes. There are proportionately more women doctorate scientists in older age groups, as was discussed in Section 2 and shown in Figure 2.1. In order to see how age affects the labor force participation, consider Table 4.3 and Figure 4.1. Table 4.3 shows numbers and percentages of doctoral scientists and engineers outside of the labor force by sex and age. Figure 4.1 shows variations in labor force participation of men and women as a function of age. For men, labor force participation remains steady (only 2-3% of men are usually outside of the labor force) up to the age of 55. After the age of 55, the percentage of men outside of the labor force increases sharply. For women the pattern is different. For all ages, women stay out of the labor force in larger proportions than men. There is also a sharp increase in the percentage of women outside of the labor force after the age of 55. However, Figure 4.1 shows that, unlike men, women below the age of 55 are most likely to stay out of the labor force between the ages of 30 and 40. The most obvious explanation is that women in this age bracket stay out of the labor force because of child rearing and other family responsibilities. The drop in the percentage of women outside of the labor force after age 40 indicates that for many women this absence from the labor force is in fact only a temporary one.

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[4] Similar analysis of labor force participation for scientists and engineers without a doctorate degree is not possible for the following reason: Labor force participation data for doctoral scientists and engineers are derived from the NRC survey; NRC defines doctorate scientists and engineers as those who either received their doctorate degrees in science and engineering or received doctorates in other fields but are working in science and engineering fields. Studies containing data on scientists and engineers of lower educational levels (e.g., the post-censal survey previously cited) do not define persons without a doctorate as scientists and engineers in an analogous way. To be fully qualified as a scientist without a doctorate other criteria such as occupation and experience in addition to education must be satisfied. This makes the definition of a "scientist outside of labor force" ambiguous, and explains the lack of data on labor force participation for the non-doctorate population.

In the recent study of John Centra[5] employment patterns of women and men with doctorates were examined in detail. This study also concludes that women doctorates are less likely than their male counterparts to be employed. The Centra study covers both science and non-science fields and does not have data on unemployed doctorates seeking employment. It is therefore not possible to analyze the labor force participation from his data in precisely the same way as was done above using data from the National Research Council survey. However, Centra obtained information on unemployed persons who preferred to be employed. Thus, defining the labor force as those employed part-time or full-time plus unemployed who prefer to be employed, the following percentages of men and women in the labor force are derived: 95.3% of men and 90.4% of women participate in the labor force.

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[5] John Centra, Women, Men and the Doctorate, Educational Testing Service, Princeton, New Jersey, 1974.

The Centra study results on unemployment and on the percentage of time since the doctorate spent without employment are given in Table 4.4 by field and sex. All unemployed persons regardless of employment preference are included in this table. Looking at material in this table, the following emerges: Immediately after receiving the doctorate, about 6% of women and less than 1% of men in all fields (science and non-science) are unemployed for one or more years. In all fields women exceed men in the percentage of time spent without employment. The figures for women in physical sciences (15.2%) and biological sciences (10.4%) are higher than for other fields. Centra's data also show that 11.1% of women and 3.8% of men were unemployed at the time of the survey.[5]

It is interesting to examine the reasons given for unemployment shown in Table 4.5. Centra finds that the majority of reasons given by women for unemployment deal with their family responsibilities and marital status; for example, pregnancy, lack of domestic help or day care for the children, anti-nepotism policies, no suitable job in husband's locale, and finally, husbands did not want their wives to work. Only 19% of women unemployed at the time of the survey and 14% of those unemployed during other periods did not work because they did not want to. The effect of marital and family status on employment patterns of women was also observed in the work of Simon, Clark and Galway done in the 60's.[6] Their survey of women doctorates two to seven years after graduation indicated that 96% of those who were unmarried were employed full-time at the time of the survey, as were 87% of the married group and 59% of the married with children group.

These data suggest, not surprisingly, that women doctorates often stay out of the labor force because of family decisions such as giving preference to a husband's career thus limiting their own career options. It is necessary to stress, however, that unemployment or lack of participation in the labor force is not synonymous with complete professional inactivity. Centra's study shows that a number of women doctorates work in their professions without pay.[7] This was also found in the survey of the American Astronomical Society membership.[8] Four people in this survey indicated that they worked full-time, but without pay, with titles like Volunteer Research Associate. Three of four women had husbands in astronomy, the other's husband was in another science. None was a volunteer by choice. Another notable example of this phenomenon was the theoretical physicist and Nobel Prize winner Maria Goeppert-Mayer, who worked as a volunteer professor at University of Chicago for many years (1946-59) including the years during which she did her Nobel Prize winning work.[9]

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[6] A.J.Simon, S.M.Clark, K. Galway, "The Woman Ph.D.: A Recent Profile," *Social Problems*, *15*, 1967, p. 221-236.

[7] Centra, John A., *Women, Men and the Doctorate*, p. 28 and 32.

[8] "Report to the Council of AAS from the Working Group on the Status of Women in Astronomy, 1972," *Bulletin*, American Astronomical Society, *6* (3), part II, 1974. In an unpublished report on women astronomers, B.T.Lynds, an astronomer at Kitt Peak National Observatory describes a typical employment pattern of many women scientists: "For example, I received my Ph.D. in 1955 and was one year unemployed, then worked 8 years half-time, 6 years three-quarters time, and only since F.Y. 1971 have I chosen to work at a full-time job in astronomy. I believe a similar background can be found for other 1950 era women astronomers..."

Before turning to a more detailed examination of unemployment and underemployment it seems relevant to analyze the extent to which men and women scientists tend to stay in the field of their training. Table 4.6 displays field-switching patterns for men and women doctoral scientists and engineers. Fields exhibiting minimal career switching are life science and psychology. About 90% of men and women doctorate recipients in these fields continue to work in them. The least retentive fields are physical sciences. Only 73% of men and 67% of women with degrees in physical sciences are still working in the field of their degree.

Physical sciences show the only marked difference in retention rates between men and women. The difference is mainly due to the difference in retention rates in chemistry. Field-switching patterns in physical sciences are examined in greater detail in Table 4.7. It shows that in chemistry 72% of men and 62% of women remain in the field. Moreover, 19% of women and 8% of men chemistry graduates work in life sciences.

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[9] Dash, Joan, A Life of One's Own, Harper and Row, New York, 1973, p. 231-346.

Women doctoral scientists and engineers are also more likely to switch into non-science fields than men: 6.7% of women and 4.7% of men are working in non-science positions. This pattern occurs in every degree field. Among doctoral scientists and engineers working full-time, 7.6% of women and 5.1% of men work in non-science fields.[10] Later in this section, it will be seen how employment in non-science positions indicates underemployment.

The unemployment and underemployment patterns of scientists and engineers will be discussed now in more detail. Unemployment and underemployment are difficult to define and determine precisely. Most of the data presented below come from the NRC survey of doctoral scientists and engineers.[11] These probably underestimate unemployment rates because, first of all, only those seeking employment are included in the calculation, thus excluding those who would like to be employed but are discouraged from seeking positions. As has been pointed out above, this is more likely to happen to women, for whom it is more socially acceptable to work professionally without pay. Secondly, unemployed persons are likely to be less visible and are thus less likely to be assessed by survey questionnaires. This response bias was observed by Centra.[12]

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[10] These numbers were computed from the NRC survey data in Table 4.11.

[11] Unemployment data from the post-censal survey with the scientist and engineer population redefined were not available to us at the time of this report.

[12] John A. Centra, Women, Men and the Doctorate, p. 16.

Table 4.8 compares the unemployment rates of women with the unemployment rates of both sexes by field. The unemployment rate of women is almost 4%, while that of the total population of doctoral scientists and engineers is about 1%. Women doctoral scientists and engineers constitute more than a quarter of those unemployed and seeking employment. The highest unemployment rates for both men and women are in physical sciences, 1.8% for both sexes and 7.3% for women; the lowest rates are in environmental sciences, 0.9% for both sexes and 1.8% for women. The ratio of female/male unemployment rates is highest in the physical and life sciences.

Unemployment rates for men and women doctoral scientists and engineers are presented in Figures 4.2 and 4.3 by age and year of doctorate respectively. The patterns are strikingly different for males and females. Figure 4.2 shows that for males the unemployment rates are almost independent of age and are below 1% between the ages of 30 and 50. For women, the highest unemployment rates occur in the youngest group, reaching a maximum of 6% between the ages of 30 and 34. From age 35 on, the female unemployment rates tend to decrease. In all age groups female unemployment rates are higher than male ones. Figure 4.3 shows similar, though not identical patterns.

For comparison, we computed unemployment rates of doctorate holders from the Centra data.[13] These are shown in Table 4.9 In his sample, the unemployment rate is about 6% for women and about 2% for men doctorates in all science and non-science fields.

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[13] John A. Centra, Women, Men and the Doctorate. The definition of unemployment and underemployment rates obtained from the Centra data are slightly different from those in the NRC survey. The difference is due to the different phrasing of questions in the two surveys. Centra's question was about the preferred employment status rather than the employment status that was sought.

Unemployment rates of scientists have also been determined in several independent surveys. A 1973 survey of the membership of the American Astronomical Society found 9% of women and 1% of men astronomers unemployed. [8] The 1971 survey of women physicists included in the roster of women in physics found that 10% of women Ph.D.'s in physics (including astronomy) were unemployed and seeking employment. [14] These unemployment rates are higher than the 7.4% rate for women doctorates in physics and astronomy given in Table 4.8.

The American Chemical Society conducts annual surveys of its membership. In the 1973 survey [15] it was found that the total unemployment rate for chemists (including all levels of educational attainment) was 4.2% for women and 1.5% for men. The corresponding rates in 1974 [16] were 3.5% for women and 1.2% for men. The 1973 unemployment rates for Ph.D. chemists [15] were 6.3% for women and 1.2% for men. In a 1974 survey of recent Ph.D.'s in chemistry, it was found that 4.5% of women and 1.2% of men were unemployed.[17]

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[14] "Women in Physics, the Report of the Committee on Women in Physics," Bulletin of the American Physical Society, June 1972, p. 740.

[15] "Report of Chemists' Salaries and Employment Status, 1973," Office of Manpower Studies, American Chemical Society, Washington, D.C., 1973.

[16] "Report of Chemists' Salaries and Employment Status, 1974," Office of Manpower Studies, American Chemical Society, Washington, D.C., 1974.

Table 4.10 shows the employment status of microbiologists for three consecutive years. The data for this table were collected in annual surveys of the membership of the American Society for Microbiology.[18] Again, we find that women have higher unemployment rates than men. For example, in 1972, 2.7% of women Ph.D.'s and 0.9% of men were unemployed and seeking employment.

All of the data examined to date consistently show significantly higher unemployment rates for women scientists and engineers. Unemployment rates are especially high for younger women. More recent data for chemists show little indication of change in these unemployment patterns. Looking at unemployment rates one cannot detect any inspiring evidence that employment opportunities for women scientists are improving.

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[17] "1974 Survey Report, Starting Salaries of Chemistry and Chemical Engineering Graduates," Office of Manpower Studies, American Chamical Society, Washington, D.C., 1974. (The sample included 66 women and 486 men who received their Ph.D.'s in 1974.)

[18] M.L. Robbins, "Status of Women Microbiologists," American Society of Microbiology News, 37 (2), April 1971; "Employment Rates and Preliminary Salary Data on ASM Membership," ASM News, 38 (4), April 1972; M.L. Robbins, "Another Look at the Profile of a Member (with Special Emphasis on the Status of the Woman Member)," ASM News, 38 (1), October 1972; P.L. Sguros, "Women in American Microbiology - a Report of Progress," ASM News, 39 (10), October 1973.

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Another aspect of the way in which persons work in the sciences is underemployment. Underemployment is even more difficult to evaluate than unemployment. In this section, the discussion will be limited to underemployment of scientists and engineers in the following three categories. Employment will be examined in part-time positions, post-doctoral positions, and non-science positions. Other indicators of underemployment, such as rank and salary will be discussed in the following section.

Data on employment by field in science and non-science positions for both full and part-time workers among doctoral scientists and engineers are presented in Table 4.11. The table also contains data on post-doctoral positions by field. It may be noted from the table that women are much more likely than men to be employed part-time. Women constitute 38% of part-time employed scientists and engineers, and 6% of those employed full-time. Figure 4.4 shows part-time employment of men and women by age. For all ages, 15% of women and 2% of men work part-time. Women are more likely to work part-time between the ages of 30 and 45 than at any other age below 65. A similar dependence on age in the percentage of women outside of the labor force was observed in Figure 4.1. It is reasonable to suppose that in this age group, women settle for part-time employment because of family responsibilities. For men, the part-time employment rate remains steady at about 1% until the age of 50; it increases after the age of 50.

Other studies confirm the higher likelihood of women than men to work part-time. Among the recent chemistry graduates, 7.6% of women Ph.D.'s and 1.4% of men worked in part-time positions in 1974.[17] A 1972 survey of women doctorates in mathematics[19] found that 16% of all those surveyed were working part-time; about a quarter of those worked part-time because no full-time position was available. Part-time employment status of microbiologists is shown in Table 4.10. This table also shows women being more likely than men to work part-time.

While some scientists and engineers work part-time by choice, it is apparent that many of them take part-time positions because no full-time employment is available. This is illustrated in Figure 4.5 and Table 4.12 which show percentages of doctoral scientists and engineers working part-time and seeking full-time employment, i.e., the underemployment rates. Part-time underemployment rates for men and women (Figure 4.5) show trends similar to the unemployment rates (Figure 4.2) as a function of age. Underemployment rates are highest for younger women and decrease after the age of 55. For men, they remain about the same for all age groups and are much lower than for women. Table 4.12 compares unemployment and part-time underemployment rates by sex and broad field categories. The total underemployment rate for women is 3.5%, five times higher than that for men (0.7%).

Underemployment in part-time positions can also be estimated from the Centra study.[20] Table 4.13 shows the relationship between the current employment status of men and women doctorates and their preferred job status. This table shows the preferred employment status according to the current employment status by sex. With the exception of men working less than half-time, the majority of men and women preferred the employment status they had. Nevertheless, a large percentage of doctorates preferred to be working more than they were. Of those working more than half-time, 17% of the women and 12% of the men would prefer to work full-time. Of those working less than half-time, 46% of the women and 67% of the men would prefer to work more. Of those unemployed, 46% of the women and 44% of the men would prefer to work part-time or full-time. For comparison, the part-time underemployment rates from the Centra Data were computed.[20] They are presented in Table 4.9. This table also illustrates the point that a much larger percentage of female than male doctorate holders are involuntarily underemployed.

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[19] "Report of the AMS Committee on Women in Mathematics, 1972," unpublished. Some of its findings are reported by Cathleen S. Morawetz, "Women in Mathematics," Notices of the American Mathematical Society, April 1973.

[20] John A. Centra, Women, Men and the Doctorate. As noted earlier, comparisons are not exact because of the wording in questionnaires. However, p. 34-36 of his report are relevant to the present discussion.

At this point, an analysis of employment in post-doctoral positions is appropriate in order to determine to what extent this type of employment represents underemployment. Post-doctoral employment by field is presented in Table 4.11 for men and women doctoral scientists and engineers. From this table, the fact emerges that women are more likely than men to be employed in post-doctoral positions. Of those employed in these positions, 13% are women while of scientists and engineers employed full-time 6% are women. Women are twice as likely as men to hold post-doctoral positions: 5% of the women in labor force hold post-doctoral positions compared to 2.4% of the men.

In addition, women tend to stay in post-doctoral positions longer than men. Table 4.14 compares men and women post-doctoral position holders by number of years since the receipt of the doctorate and by broad field category. In all fields 34% of women and 23% of men in post-doctoral positions held their degrees for 4 or more years. This trend is most pronounced in physical and mathematical sciences, where almost half of the women and only one-fifth of the men held post-doctoral positions for 4 or more years after their degrees.

Reasons for accepting a post-doctoral position are given in Tables 4.15 and 4.16. In Table 4.15, they are shown by sex and by broad field category. In this latter table, the underemployment rate of post-doctoral scientists, i.e., the percentage in the labor force of scientists in post-doctoral positions who hold these particular slots because no other job was available is shown. As can be expected, the underemployment rate of women is higher than that of men in every field category. It is worse in natural sciences than in social sciences.

The preponderance of women scientists in post-doctoral positions has been observed in other studies as well. The 1971 American Society for Microbiology survey of its membership showed 30% of women and 11% of men doctorates in microbiology holding positions of post-doctoral fellow or research associate.[21] A survey of psychology departments [22] found that in 1972 women held 48% of the research appointments but constituted only 14% of the full-time faculty; in 1973 49% of research appointees and 16% of full-time faculty were women. A study of the academic employment of anthropologists found that in all departments at 277 institutions women constituted 18% of anthropologists and 29% of those women were in research associate positions in 1971-72. Three years later, (1974-75), at the same institutions women comprised 22% of all anthropologists and 42% of research associates.[23]

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[21] Kashket, Robbins, Leive, Huang, "Status of Women Microbiologists," Science, 88, February 1974, p. 488.

[22] "Survey of Departments of Psychology, 1972-73," American Psychological Association Committee on Women in Psychology, APA, Washington, D.C., 1974 (unpublished report.)

A survey of recent graduates in chemistry[17] found 47% of women and 42.6% of men Ph.D.'s in post-doctoral appointments. The tendency of women to remain in post-doctoral positions for longer periods of time was observed among women mathematicians, especially among the older ones. A survey of women doctorates in mathematics[19] found that research associateships were held by women about two years on the average; however, among women who received their doctorates before 1962, relatively larger fractions were in research positions which they held for about four years. The American Astronomical Society membership [8] survey found one-third of women astronomers and only one-sixth of men in the field in post-doctoral or research associate positions. Similarly, a survey of 28 graduate departments in astronomy found 52% of women and 35% of men Ph.D.'s in research assistant or research associate positions during the ten year period 1962-72. It was also found that a large fraction of women astronomers complained of holding dead end jobs with no advancement possibility.[8]

On the whole, these studies show larger fractions of women in post-doctoral or research positions than indicated in the NRC survey (see Table 4.11). Thus, it would appear that the estimate of underemployment presented here which was calculated from the NRC data on post-doctoral positions (Table 4.16) should be regarded only as the lower limit.

To complete the discussion of underemployment of scientists and engineers, their employment in non-science positions will be considered. Earlier it was

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[23] Carole Vance, "Sexual Stratification in Academic Anthropology 1974-75," Anthropology Newsletter, April 1975.

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noted that a larger proportion of women than men scientists work in non-science positions. This is illustrated in Tables 4.6, 4.11 and 4.17. Table 4.17 gives the percentage of doctoral scientists and engineers in non-science positions by sex and broad field category. From this table, it is seen that among full-time workers in every field category, a larger fraction of women than men work in non-science positions. This trend is more marked in the natural sciences than in the social sciences; the largest disparity occurs in life science where the proportion of women in non-science positions is about twice as high as that of men.

Reasons for taking non-science positions for full-time employed doctoral scientists and engineers are presented in Table 4.18. The data in this table illustrate the degree of underemployment in non-science positions. It is apparent that slightly more women (0.4%) than men (0.3%) are underemployed, i.e., working in non-science positions because no science position is available. It should be noted that the above numbers are only very rough estimates of underemployment rates in non-science positions. The NRC survey provides very little information about the nature of these positions. Lacking this information, it is difficult to assess the degree of underemployment in non-science positions more accurately. Data from other surveys would seem to indicate that the estimates of underemployment rates in non-science positions from NRC data are probably too low.[24]

The unemployment and underemployment rates obtained from the NAS-NRC survey of doctoral scientists and engineers are summarized in Table 4.19. As was noted previously, the numbers in the table appear to underestimate unemployment and underemployment and should be regarded as the lower limit. These data together with the findings of numerous other surveys clearly show that unemployment and underemployment in science and engineering is much more prevalent among women than among men. Moreover, this disparity is worst for younger women. In addition, it appears that the disparity in the employment status between men and women is worse in natural sciences than in other fields. Thus, from the data presented, the substantial improvement in the employment status of women (taking into account all the ramifications of that term) is not readily discerned.

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[24] Similar data were collected for the field of microbiology and are shown in Table 4.10. This table shows a larger proportion of women (1.4% in 1971 and 1.1% in 1972) than men (0.7% in 1971 and 1972) doctorates in microbiology are working in a field not related to their training and are seeking work in a related field.

Table 4.1

EMPLOYED LABOR FORCE PARTICIPATION OF PERSONS WITH 4 OR MORE YEARS OF COLLEGE EDUCATION BY SEX AND AGE. (MARCH 1971)

	Persons with 4 or more years of college		
Sex and Race	Total Number (in thousands)	Number with Income (in thousands)	With Income %
Males (Total)	8,488	7,457	87.9
White	8,088	7,246	89.6
Black	400	211	52.8
Females (Total)	5,793	3,784	65.3
White	5,405	3,558	65.8
Black	388	226	58.2

Source: "The 1973 World Almanac and Book of Facts", Newspaper Enterprise Association, New York, N.Y. (calculated from tables on pp. 331 and 332); original source: Bureau of Census.

TABLE 4.2

LABOR FORCE[1] PARTICIPATION OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND FIELD

	BOTH SEXES		MEN		WOMEN	
FIELD[2]	No. in Labor Force	% in Labor Force	No. in Labor Force	% in Labor Force	No. in Labor Force	% in Labor Force
All Fields	229,392	93.7	211,346	94.5	18,046	84.9
Phys. Sc.	49,999	93.6	47,977	94.2	2,022	81.3
Chemistry	31,428	92.8	29,865	93.5	1,563	80.2
Physics/ Astron.	18,571	95.0	18,112	95.3	459	85.6
Math. Sc.	12,790	94.6	11,946	95.4	844	85.1
Mathematics	11,293	94.2	10,526	95.1	767	83.8
Statistics	1,497	97.8	1,420	97.7	77	100.0
Computer Sc.	2,914	99.0	2,826	99.1	88	97.8
Environmental Sc.	10,631	96.0	10,352	96.1	279	90.9
Earth Sc.	8,768	95.9	8,554	96.0	214	90.7
Oceanography	1,180	96.2	1,134	96.7	46	85.2
Atmo. Sc.	683	96.9	666	94.5	17	100.0
Engineers	36,464	97.1	36,317	97.1	147	89.1
Life Science	59,922	92.9	53,536	94.2	6,386	83.0
Bio. Sc.	37,941	92.5	32,774	94.1	5,167	83.2
Agric. Sc.	11,204	94.2	11,055	94.3	149	85.1
Medic. Sc.	10,813	93.1	9,743	94.6	1,070	81.8
Psychology	26,289	92.9	21,167	94.0	5,122	88.7
Social Sc.	30,134	92.0	27,012	92.5	3,122	87.2
Economics	8,775	90.7	8,257	91.1	518	84.9
Sociol/ Anthrop.	6,878	92.3	5,588	93.0	1,290	89.3
Other Soc. Sc.	14,481	92.6	13,167	93.3	1,314	86.0
No Report	213	26.8	175	27.7	38	23.0

[1] Labor force is defined as all those employed both full-time and part-time plus unemployed, seeking employment.

[2] Field is field of employment or field of doctorate if unemployed or working in non-science positions.

SOURCE: "Characteristics of Doctoral Scientists and Engineers in the United States, 1973", NSF 75-312-A, Washington, D.C. 1975 (Based on data from the 1973 Survey of Doctoral Scientists and Engineers.)

Table 4.3

DOCTORAL SCIENTISTS AND ENGINEERS OUTSIDE OF THE LABOR FORCE BY AGE AND SEX

Age	Total No.	Men No.	Men %	Women No.	Women %
Total	15,528	12,314		3,214	
Under 30	297	214	1.8	83	2.7
30-34	1,826	1,333	11.0	493	16.1
35-39	1,184	845	7.0	399	11.1
40-44	1,171	955	7.9	216	7.1
45-49	977	752	6.2	225	7.4
50-54	981	809	6.7	172	5.6
55-59	940	749	6.2	191	6.3
60-64	1,334	1,074	8.9	260	8.5
65 and over	6,408	5,333	44.2	1,075	35.2
No Report	410	250		160	

Percentages were computed only for those reporting age.

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

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Table 4.4

UNEMPLOYMENT OF MEN AND WOMEN DOCTORATES *

Field	Percentage Unemployed for One or More Years Immediately After Receiving the Doctorate		Percentage of Time Unemployed Since Doctorate	
	Women	Men	Women	Men
All	5.7	0.8	7.5	0.4
Education	2.9	0.2	3.3	0.2
Humanities	7.1	1.2	7.5	0.4
Soc. Sc.	8.8	1.8	8.2	0.4
Biol. Sc.	5.7	0.6	10.4	0.2
Physical Sc.	5.8	0.5	15.2	1.1

* All unemployed persons regardless of employment preference.

Source: John A. Centra, "Women, Men and the Doctorate", Educational Testing Service, Princeton, New Jersey, September 1974 (from data on pp. 28 and 32).

TABLE 4.5

REASONS FOR CURRENT AND OTHER PERIODS OF UNEMPLOYMENT

Reasons for Unemployment[1]	Number and Percentage (in parentheses) of Total Responses for Each Reason[2]: Current Unemployment W 142 responses	Current Unemployment M 12 responses	Other Periods of Unemployment W 524 responses	Other Periods of Unemployment M 20 responses
I did not receive an offer	13 (9)	7 (58)	39 (7)	5 (25)
I received an offer but I felt that it was not commensurate with my ability, training or interests	9 (6)	1 (8)	19 (4)	2 (10)
I received an offer but did not like the geographical location	4 (3)	0	8 (2)	1 (5)
No suitable jobs were available in the same locale as spouse's job	21 (15)	0	86 (16)	0
I was not employed because of anti-nepotism policy of spouse's employer	13 (9)	0	43 (8)	0
I was pregnant	6 (4)	0	103 (20)	0
I had poor health	7 (5)	0	15 (3)	2 (10)
I did not want to work	27 (19)	1 (8)	74 (14)	4 (20)
Spouse did not want me to work	6 (4)	0	20 (4)	0
I did not want to teach	4 (3)	0	10 (2)	0
I could not find competent domestic help or day care for children	11 (8)	0	47 (9)	0
Other	22 (15)	3 (25)	60 (11)	6 (30)

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[1] Excluding retirement.

[2] Based on those who responded to this question.

SOURCE: John A. Centra "Women, Men and the Doctorate" Educational Testing Service, Princeton, New Jersey, September 1974, Table 3.12 on page 26.

TABLE 4.6

FLOW OF DOCTORAL SCIENTISTS AND ENGINEERS FROM FIELD OF DOCTORATE TO FIELD OF EMPLOYMENT

Men

Field of Employment	Field of Doctorate Phys.Sc. %	Math.Sc. %	Comp.Sc. %	Env.Sc. %	Engr. %	Life Sc. %	Psych. %	Soc.Sc. %	Non-Sc. %	No Rep. %
Physical Sc.	72.8	0.8	—	1.8	4.8	2.2	0.1	—	4.3	14.3
Mathematical Sc.	0.7	83.1	10.4	0.1	1.2	0.2	0.5	0.7	11.8	17.0
Computer Sc.	0.9	5.8	77.0	0.6	2.4	—	0.5	0.3	1.7	—
Environmental Sc.	2.8	0.7	—	88.1	2.1	2.3	0.1	0.9	1.7	2.7
Engineering	8.7	4.4	8.1	3.7	88.3	0.7	0.5	0.6	3.5	12.2
Life Sc.	6.7	1.7	—	2.1	0.9	89.5	2.2	4.0	4.4	32.6
Psychology	—	0.2	—	—	0.1	0.2	88.2	0.8	50.9	2.0
Social Sc.	0.2	0.3	1.4	0.2	0.4	0.6	1.5	80.4	19.8	13.6
Non-Science	5.1	2.1	1.4	2.3	3.7	2.9	5.5	10.7	—	4.1
No Report	2.1	0.9	1.6	1.2	1.2	1.4	0.9	1.6	1.9	1.4

Women

Field of Employment	Field of Doctorate Phys.Sc. %	Math.Sc. %	Comp.Sc. %	Env.Sc. %	Engr. %	Life Sc. %	Psych. %	Soc.Sc. %	Non-Sc. %	No Rep. %
Physical Sc.	66.6	0.4	—	5.5	14.2	2.0	—	0.2	2.7	10.8
Mathematical Sc.	0.9	84.5	25.0	—	4.7	0.2	0.1	0.2	8.1	—
Computer Sc.	1.3	4.3	58.3	—	2.8	—	—	0.3	0.2	—
Environmental Sc.	1.6	—	—	80.6	—	1.5	—	0.2	0.7	—
Engineering	1.3	0.7	8.3	2.4	73.6	0.2	—	0.1	0.2	—
Life Sc.	15.6	3.2	—	6.7	—	88.3	1.4	2.6	6.0	40.5
Psychology	0.1	0.1	—	—	—	0.5	91.0	1.6	67.7	—
Social Sc.	0.3	—	—	—	—	0.3	1.1	81.0	13.1	8.1
Non-Science	8.8	4.2	—	4.2	4.7	5.7	5.3	12.4	—	—
No Report	3.5	2.6	8.3	0.6	—	1.3	1.1	1.6	1.4	40.5

SOURCE: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

Table 4.7

FLOW OF DOCTORAL PHYSICAL SCIENTISTS FROM FIELD OF DOCTORATE TO FIELD OF EMPLOYMENT BY SEX

	Field of Doctorate			
	Chemistry		Physics	
Field of Employment	Women	Men	Women	Men
Chemistry	62.4%	71.8%	1.2%	1.3%
Physics	2.5	2.1	72.2	69.5
Mathematical Science	0.1	0.2	4.5	1.7
Computer Science	0.8	0.4	3.3	1.6
Enviromental Science	1.4	2.4	2.1	3.5
Engineering	0.9	5.9	2.8	13.3
Bioscience	14.5	5.9	2.8	2.0
Agricultural Science	0.8	0.9	-	0.1
Medical Science	3.3	2.1	0.5	0.8
Psychology	-	-	0.5	0.1
Economics	0.1	-	1.2	-
Sociology/Anthropology	-	-	-	-
Other Social Science	0.1	-	1.2	0.3
Non-Science	9.5	5.7	5.7	4.2
No Report	3.5	2.5	3.3	1.5

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

Table 4.8

UNEMPLOYMENT OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND FIELD

	BOTH SEXES		WOMEN			
FIELD	Number Unemployed	Unemployment Rate[1]	Number Unemployed	Unemployment Rate[1]	Women as % of unemployed population	Ratio of female to male unemployment rates
All Fields	2,642	1.2	705	3.9	26.7	4.3
Physical Sc.	889	1.8	148	7.3	16.6	4.9
Chemistry	569	1.8	114	7.3	20.0	-
Physics/ Astron.	320	1.7	34	7.4	10.6	-
Math. Sc.	183	1.4	25	3.0	13.7	2.2
Mathematics	181	1.6	25	3.2	13.8	-
Statistics	2	0.1	-	-	-	-
Computer Sc.	-	-	-	-	-	-
Environmental Sc.	94	0.9	5	1.8	5.3	2.1
Earth Sc.	80	0.9	4	1.9	5.0	-
Oceanography	14	1.2	1	2.2	7.1	-
Atmospheric Sc.	-	-	-	-	-	-
Engineers	277	0.8	8	5.4	28.9	7.3
Life Science	608	1.0	274	4.3	45.1	7.2
Biolog. Sc.	500	1.3	245	4.7	49.0	
Agr. Sc.	88	0.8	21	14.1	25.9	-
Medic. Sc.	20	0.2	8	0.8	40.0	-
Psychology	252	1.0	130	2.5	51.6	4.2
Social Sc.	269	0.9	90	2.9	33.5	4.4
Economics	41	0.5	9	1.7	22.0	-
Sociolog./ Anthrop.	97	1.4	36	2.8	37.1	-
Other Soc.Sc.	131	0.9	45	3.4	34.4	-
No Report	70	32.9	25	65.8	35.7	-

[1] Unemployment rate is computed only for those seeking employment. Labor force participation figures of Table were used for unemployment rates.

Source: "Characteristics of Doctoral Scientists and Engineers in the United States, 1973", NSF 75-312-A, Washington, D.C., 1975 (based on data from the 1973 survey of doctoral scientists and engineers).

Table 4.9

UNEMPLOYMENT AND UNDEREMPLOYMENT OF DOCTORATE HOLDERS

Percent in labor force[1]		Unemployment Rate[2]		Underemployment Rate[3]	
Men	Women	Men	Women	Men	Women
95.3	90.4	1.7	5.6	0.4	3.3

[1] Labor force is defined as all those employed part-time and full-time plus unemployed who prefer to be unemployed.

[2] Unemployment rate includes unemployed who prefer to be employed.

[3] Underemployment rate includes part-time employed who prefer to work more.

Source: John A. Centra, "Women, Men and the Doctorate", Educational Testing Service, Princeton, New Jersey, 1974 (from data on pp.34 and 36).

Table 4.10

EMPLOYMENT STATUS OF MICROBIOLOGISTS FOR THREE CONSECUTIVE YEARS BY SEX AND EDUCATIONAL LEVEL

Educational Level	1970 men	1970 women	1971 men	1971 women	1972 men	1972 women
All Degrees						
Total number	10,858	3,275	11,458	3,766	12,055	4,263
(1) Employed full-time[1]	91.3%	84.8%	87.2%	79.9%	84.8%	76.4%
(2) Employed part-time[1]	4.2	6.8	3.7	6.5	4.1	7.7
(3) Employed in field unrelated to training	0.7	0.5	4.0	3.1	4.1	3.5
(4) Seeking related field[1,2]			0.8	1.2	0.7	0.6
(5) Unemployed, not seeking	2.9	5.6	2.7	6.2	1.1	4.9
(6) Unemployed, seeking	0.9	2.3	1.6	3.1	2.4	4.9
Ph.D./Sc.D.						
Total number	6,031	1,160	6,441	1,311	6,627	1,333
(1) Employed full-time[1]	96.8%	86.5%	92.8%	81.7%	90.8%	83.0%
(2) Employed part-time[1]	1.3	6.7	1.9	6.2	1.8	7.0
(3) Employed in field unrelated to training	0.5	0.4	3.4	3.3	3.6	1.8
) Seeking related field[1,2]			0.7	1.4	0.7	1.1
5) Unemployed, not seeking	1.1	3.6	1.1	4.5	0.9	1.8
(6) Unemployed, seeking	0.3	2.8	0.2	2.9	0.9	2.7

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[1] In 1971 and 1972 employment categories were designated as follows: (1) employed full-time in field for which trained, (2) employed part-time in field for which trained, (4) employed in field unrelated to training and seeking related field.

[2] This employment category did not appear in 1970

Source: M.L. Robbins, "Status of Women Microbiologists", ASM News 37 (2), April 1971; "Employment Rates and Preliminary Salary Data on ASM Membership", ASM News 38 (4), April 1972; M.L. Robbins, Another Look at the Profile of a Member (with Special Emphasis on the Status of the Woman Member)", ASM News 38 (10), October 1972; P.L. Sguros, "Women in American Microbiology - a Report of Progress", ASM News 39 (10), October 1973; Kashket, Robbins, Leive, Huang, "Status of Women Microbiologists", Science 88, 488, February 1974.

Table 4.11

FULL-TIME AND PART-TIME EMPLOYMENT BY SEX AND FIELD OF DOCTORAL SCIENTISTS AND ENGINEERS

	FULL-TIME						PART-TIME						POST-DOCTORAL		
	Total			Non-Science			Total			Non-Science					
Field	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %	Total No.	Women No.	Women %
All Fields	213,611	13,706	6.4	11,179	1,036	9.3	7,180	2,736	38.1	760	220	28.9	5,959	899	15.1
Physical Sc.	45,826	1,383	3.0	3,043	151	5.0	1,311	346	29.4	304	65	21.4	1,973	145	7.4
Chemistry	28,920	1,072	3.7	2,182	132	6.0	838	254	30.3	195	55	28.2	1,101	123	11.2
Physics/Astron.	16,906	311	1.8	861	19	2.2	473	92	19.4	99	10	10.1	872	22	2.5
Mathematical Sc.	12,244	694	5.7	274	26	9.5	255	121	47.4	17	10	58.8	108	4	3.7
Mathematics	10,775	632	5.9	244	26	10.7	229	106	46.3	15	8	53.4	108	4	3.7
Statistics	1,469	62	4.2	30	-	-	26	15	57.7	2	2	100.0	-	-	-
Computer Sc.	2,858	80	2.8	21	-	-	28	8	28.6	-	-	-	28	-	-
Environmental Sc.	10,062	208	2.1	177	2	1.1	296	55	18.6	12	3	25.0	179	9	5.0
Earth Sc.	8,308	165	2.0	158	2	1.3	253	37	14.6	12	3	25.0	127	8	6.3
Oceanography	1,108	35	3.2	18	-	-	35	10	28.6	-	-	-	23	-	-
Atmospheric Sc.	646	8	1.2	1	-	-	8	8	100.0	-	-	-	29	1	3.5
Engineers	35,303	125	0.4	1,303	5	0.3	651	14	2.2	42	-	-	233	-	-
Life Science	54,636	4,779	8.8	1,833	290	15.8	1,797	720	40.1	160	68	42.5	2,917	613	21.0
Biolog. Sc.	33,788	3,770	11.2	1,290	219	17.0	1,222	607	49.7	135	60	44.4	2,431	545	22.4
Agric. Sc.	10,815	110	10.2	330	17	5.2	220	15	6.8	17	-	-	81	2	2.5
Medic. Sc.	10,033	899	9.0	213	54	25.4	355	97	27.3	8	8	100.0	405	66	16.3
Psychology	24,063	3,830	15.9	1,197	223	18.6	1,716	1,069	62.3	72	23	31.9	258	93	36.0
Social Science	28,497	2,600	9.1	3,324	337	10.1	1,106	398	36.0	150	50	33.3	262	34	13.0
Economics	8,467	457	5.4	1,196	53	4.4	241	49	20.3	36	3	8.3	26	3	11.5
Sociol./Anthrop.	6,404	1,049	16.4	431	94	21.8	305	188	61.6	40	18	45.0	72	17	23.6
Other Soc. Sc.	13,626	1,094	8.0	1,697	190	11.2	560	161	28.8	74	29	39.2	164	14	8.5
No Report	122	7	5.7	7	2	28.6	20	5	20.0	3	1	33.3	1	1	100.0

Source: "Characteristics of Doctoral Scientists and Engineers in the United States, 1973", NSF 75-312-A. Washington, D.C. 1975 (based on data from the 1973 Survey of Doctoral Scientists and Engineers).

Table 4[illegible]2

UNEMPLOYMENT AND UNDEREMPLOYMENT OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND FIELD OF IDENTIFICATION

FIELD OF IDENTIFICATION[1]	Labor Force[2]		Unemployment Rate[3]		Underemployment Rate (in part-time positions)[4]	
	Men	Women	Men	Women	Men	Women
All Fields	211,345	18,046	0.9	3.9	0.7	3.5
Physical and Mathematical Sciences[5]	103,211	3,042	1.2	5.8	0.8	4.7
Life Science	51,381	5,980	0.6	4.6	0.5	3.4
Psychology	20,008	4,853	0.6	2.8	0.5	3.8
Social Science	23,742	2,703	0.7	3.2	1.1	3.9

[1] Field of employment or field of degree if unemployed.

[2] All persons employed part-time or full-time plus unemployed and seeking.

[3] Only those seeking employment are included in the calculation of unemployment rates.

[4] Underemployment rate includes only part-time employed seeking full-time employment.

[5] Includes physical, mathematical, and environmental scientists, computer specialists and engineers.

Source: NAS/NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

Table 4.13

Current Employment
vs.
The Preferred Employment Status of Each Person

	Current Employment Status							
	Full-time		Over Half-time		Less than Half-time		Not Employed	
Preferred Employment Status	W (1187)	M (1527)	W (101)	M[1] (16)	W (68)	M[1] (9)	W (168)	M (61)
Full-time	88%	91%	17%	12%	22%	22%	13%	26%*
Over half-time	10	7**	80	69	24	45	18 } 33	8 } 18
Less than half-time	1	1	3	19	54	33	15	10
Not employed	1	1	0	0	0	0	54	56

[1] The small numbers of men employed part time make comparisons with women tenuous for these categories.

*p<.05 Chi-square tests of significance of percentage differences between sexes

**p<.01 Chi-square tests of significance of percentage differences between sexes

Source: John A. Centra "Women, Men, and the Doctorate", Educational Testing Service, Princeton, New Jersey, September, 1974 (table 3.7 on page 36).

Table 4.14

DISTRIBUTION OF DOCTORAL SCIENTISTS AND ENGINEERS IN POST-DOCTORAL POSITIONS BY SEX, BROAD FIELD CATEGORY AND NUMBER OF YEARS SINCE DOCTORATE
(in percent)

Years since Doctorate	All Fields				Physical and Math. Science				Life Science				Psychology/ Social Science			
	Men		Women		Men		Women		Men		Women		Men		Women	
Total	100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0	
1 year	27.4		18.7		28.0		17.5		25.5		19.6		9.3		17.0	
2 years	32.4		34.2		30.9		25.5		37.0		39.3		23.1		26.7	
3 years	19.6		13.5		20.3		11.5		18.2		13.5		21.4		17.0	
4-9 years	19.1	22.6	26.9	33.6	18.3	20.8	28.5	45.5	17.4	19.3	24.6	27.6	31.9	46.2	31.9	39.3
10 or more years	3.5		6.7		2.5		17.0		1.9		3.0		14.3		7.4	

Source: NAS/NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

Table 4.15

DOCTORAL SCIENTISTS AND ENGINEERS: REASON FOR TAKING A POST-DOCTORAL POSITION BY SEX AND NUMBER OF YEARS SINCE DOCTORATE

Sex and Number of years since Doctorate	Total	Seek Experience	Change Field	No Other Job	Other
Men					
Total	5,065	44.3%	13.1%	37.5%	5.6%
1 year	1,285	56.8	13.8	25.8	3.7
2 years	1,642	44.1	14.4	39.3	2.2
3 years	991	38.3	8.7	46.2	6.6
4-9 years	969	35.4	13.4	45.2	4.9
10 or more years	178	37.6	18.0	15.7	21.3
Women					
Total	904	51.4%	12.8%	29.8%	5.9%
1 year	169	68.0	13.0	16.0	3.0
2 years	309	57.3	16.8	23.6	2.3
3 years	122	44.3	7.4	44.3	3.3
4-9 years	243	40.7	9.9	37.0	12.3
10 or more years	61	32.8	14.8	41.0	11.5

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

Table 4.16

DOCTORAL SCIENTISTS AND ENGINEERS: REASON FOR TAKING A POST-DOCTORAL POSITION BY SEX AND BROAD FIELD CATEGORY

FIELD AND SEX	Total	Seek Additional Experience	To Change Field	No Other Job Available	Other	Underemployment Rate[1]
Men						
All Fields	5,065	44.3	13.1	37.5	4.6	0.9
Physical and Math. Sc.	2,644	36.9	15.4	45.2	2.0	1.2
Life Science	1,982	52.2	10.4	32.5	4.9	1.3
Psychology and Sociology	398	52.3	10.8	14.8	19.1	0.1
Women						
All Fields	904	51.4	12.8	29.8	5.9	1.5
Physical and Math. Sc.	200	36.0	11.0	42.0	10.5	2.8
Life Science	565	54.7	12.7	28.3	4.2	2.7
Psychology and Sociology	135	60.7	16.3	17.0	5.9	0.2

[1] Underemployment rate is the percentage of post-doctoral scientists in the labor force who hold their jobs because no other position is available.

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

Table 4.17

PERCENTAGE OF DOCTORAL SCIENTISTS AND ENGINEERS IN NON-SCIENCE POSITIONS BY SEX AND BROAD FIELD CATEGORY

	Full-Time		Part-Time	
	Men	Women	Men	Women
All Fields	5.1	7.6	12.2	8.0
Physical and Math. Sc.[1]	4.5	7.4	14.9	14.3
Life Science	3.1	6.1	8.5	9.4
Psychology	4.8	5.8	7.6	2.2
Social Science	11.5	13.0	14.1	18.0

[1] Includes physical, mathematical, and environmental scientists, computer specialists and engineers.

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

Table 4.18

REASONS FOR TAKING NON-SCIENCE POSITIONS FOR FULL-TIME EMPLOYED DOCTORAL SCIENTISTS AND ENGINEERS

	% of non-science position holders		% of labor force	
	men	women	men	women
Total number	10,136	1,034		
(1) Prefer non-science position	14.6	17.8	0.7	1.4
(2) Promoted out	13.3	10.2	0.7	0.8
(3) Better pay	4.3	1.8	0.2	0.1
(4) Prefer locale	1.1	1.5	0.1	0.1
(5) No science position available[1]	5.6	5.1	0.3	0.4
(6) Other	8.1	12.7	0.4	1.0
(7) No report	53.0	50.9	2.7	3.9

[1] Last two columns represent underemployment rates

Source: NAS- NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

Table 4.19

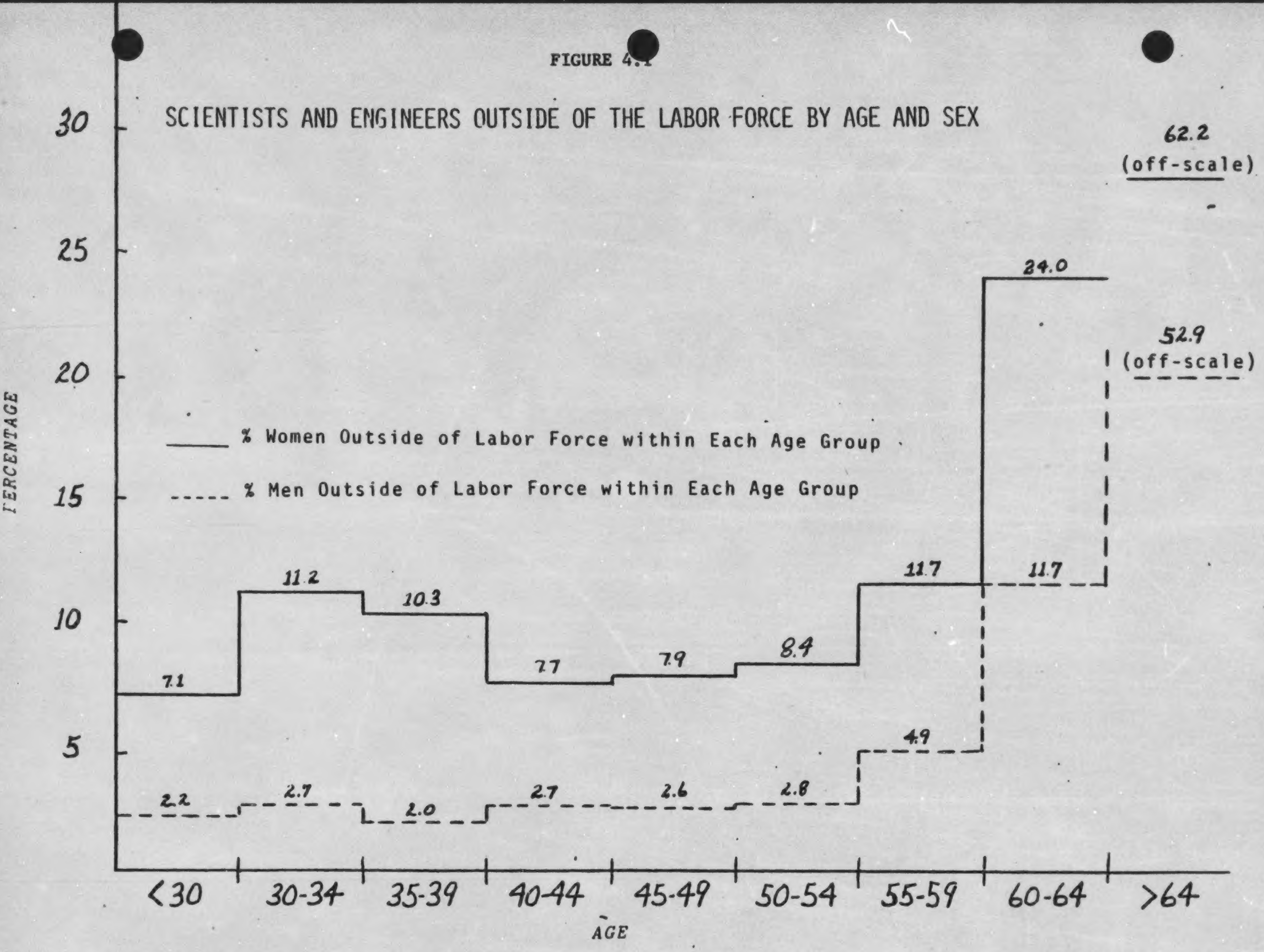
UNEMPLOYMENT AND UNDEREMPLOYMENT RATES OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX

	men	women
Unemployment rate	0.9	3.9
Underemployment rate		
in part-time positions	0.7	3.5
in post-doc. positions	0.9	1.5
in non-science positions	0.3	0.4
total	1.9	5.4
Total unemployment and underemployment rate	2.8	9.3

Source: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

FIGURE 4.1

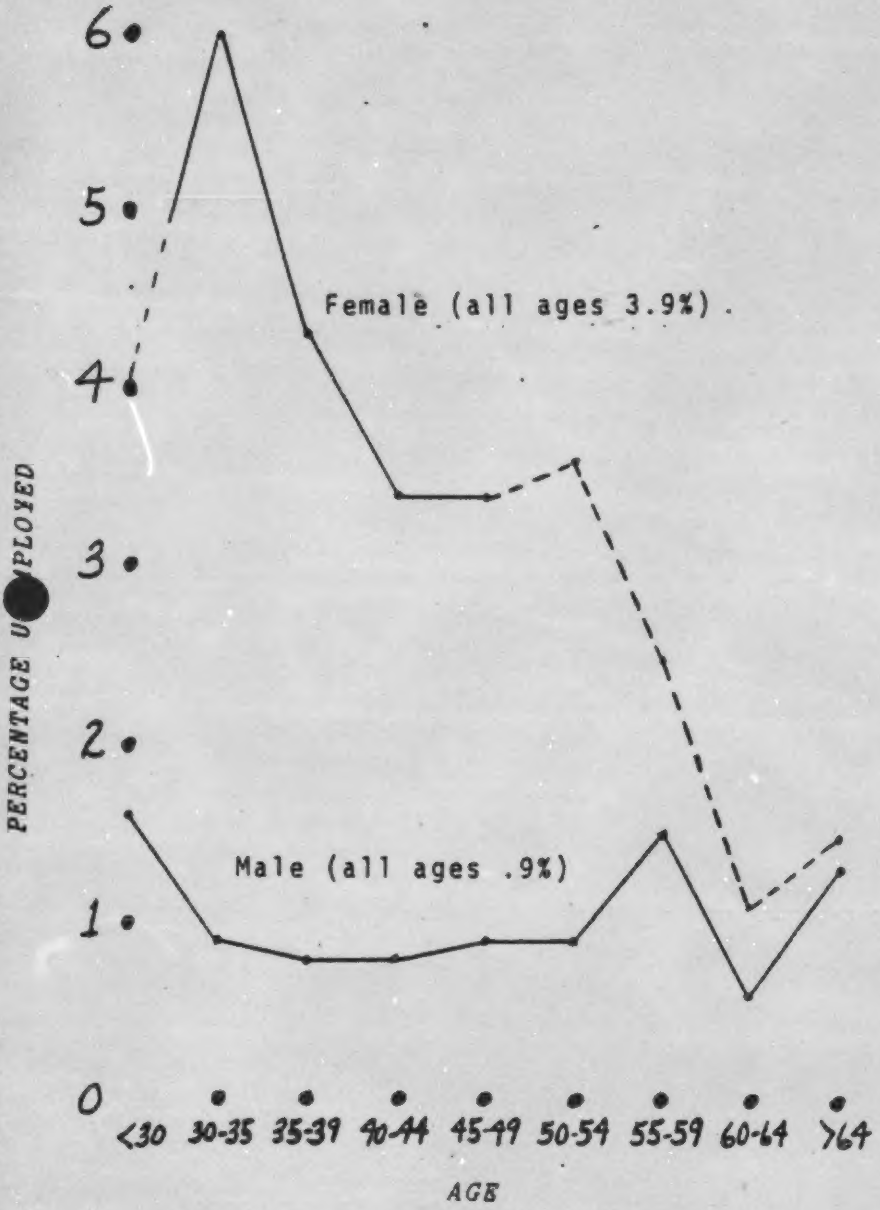
SCIENTISTS AND ENGINEERS OUTSIDE OF THE LABOR FORCE BY AGE AND SEX



SOURCE: NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

Figure 4.2

UNEMPLOYMENT RATES OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND AGE

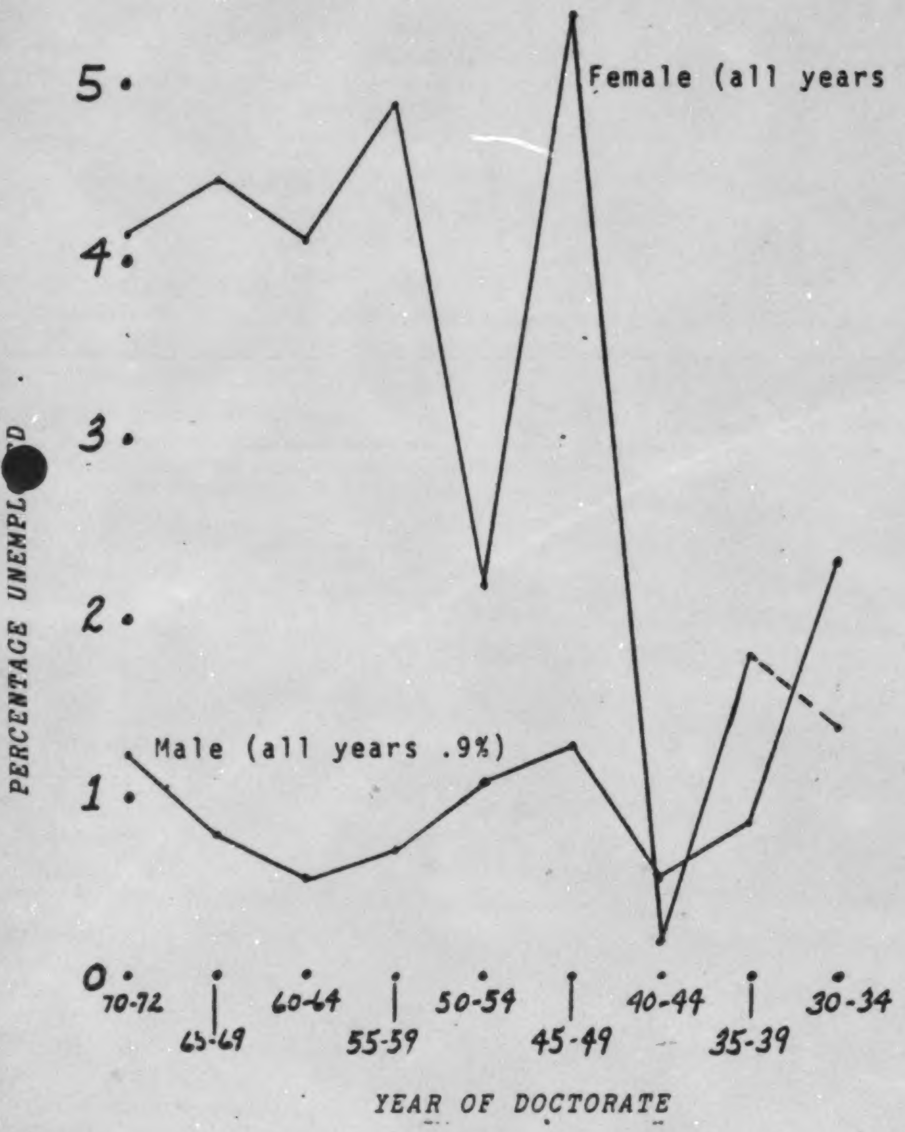


NOTE: Interrupted lines indicate that unemployment rates are based on labor force too small to be reliable.

Source: "Doctoral Scientists and Engineers in the United States, 1973 Profile", National Academy of Sciences, Washington, D.C., March 1974 (based on data from the 1973 Survey of Doctoral Scientists and Engineers).

Figure 4.3

UNEMPLOYMENT RATES OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND YEAR OF DOCTORATE

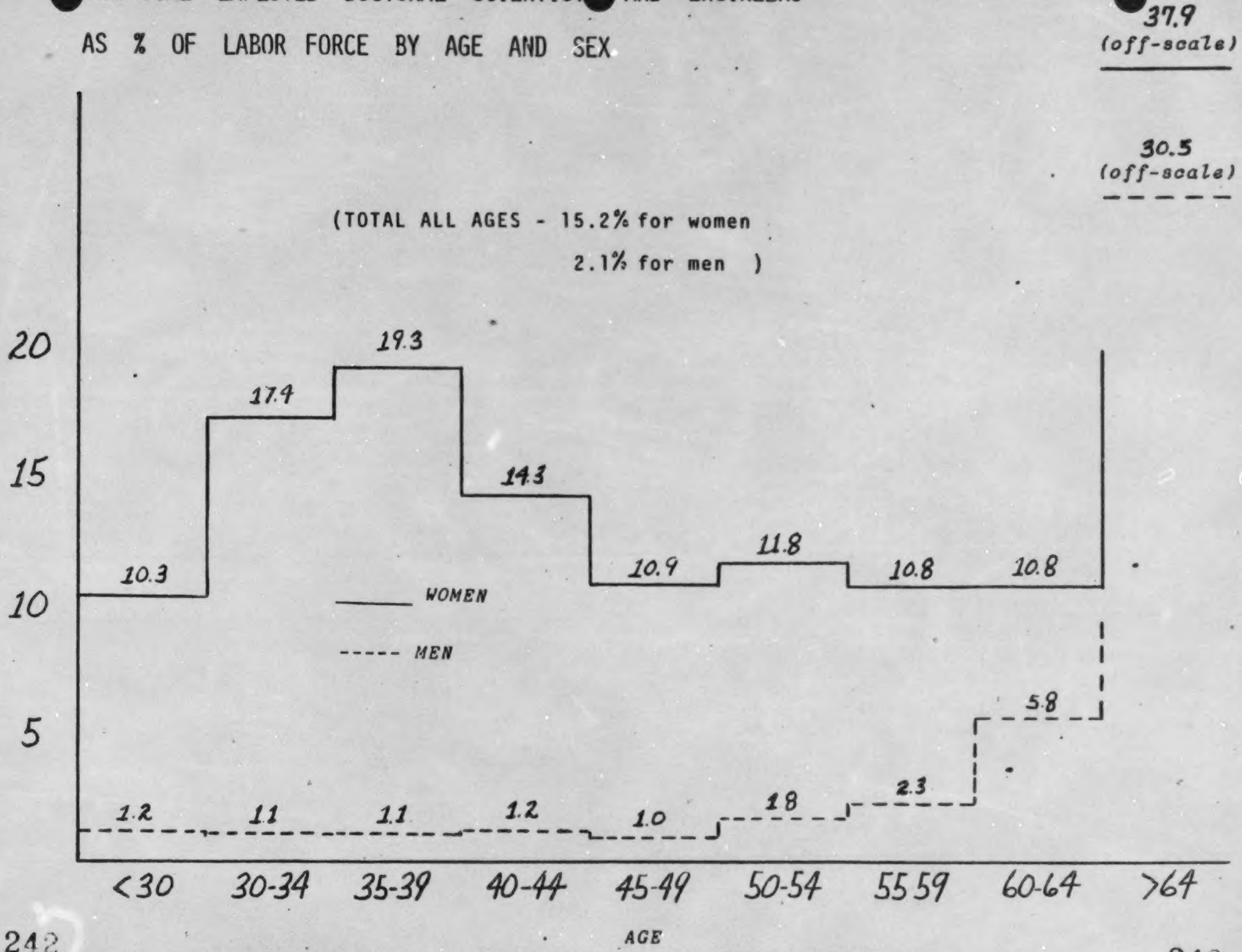


NOTE: Interrupted lines indicate that data points are based on fewer than 100 sample cases.

Source: NAS/NRC Survey of Doctoral Scientists and Engineers, 1973.

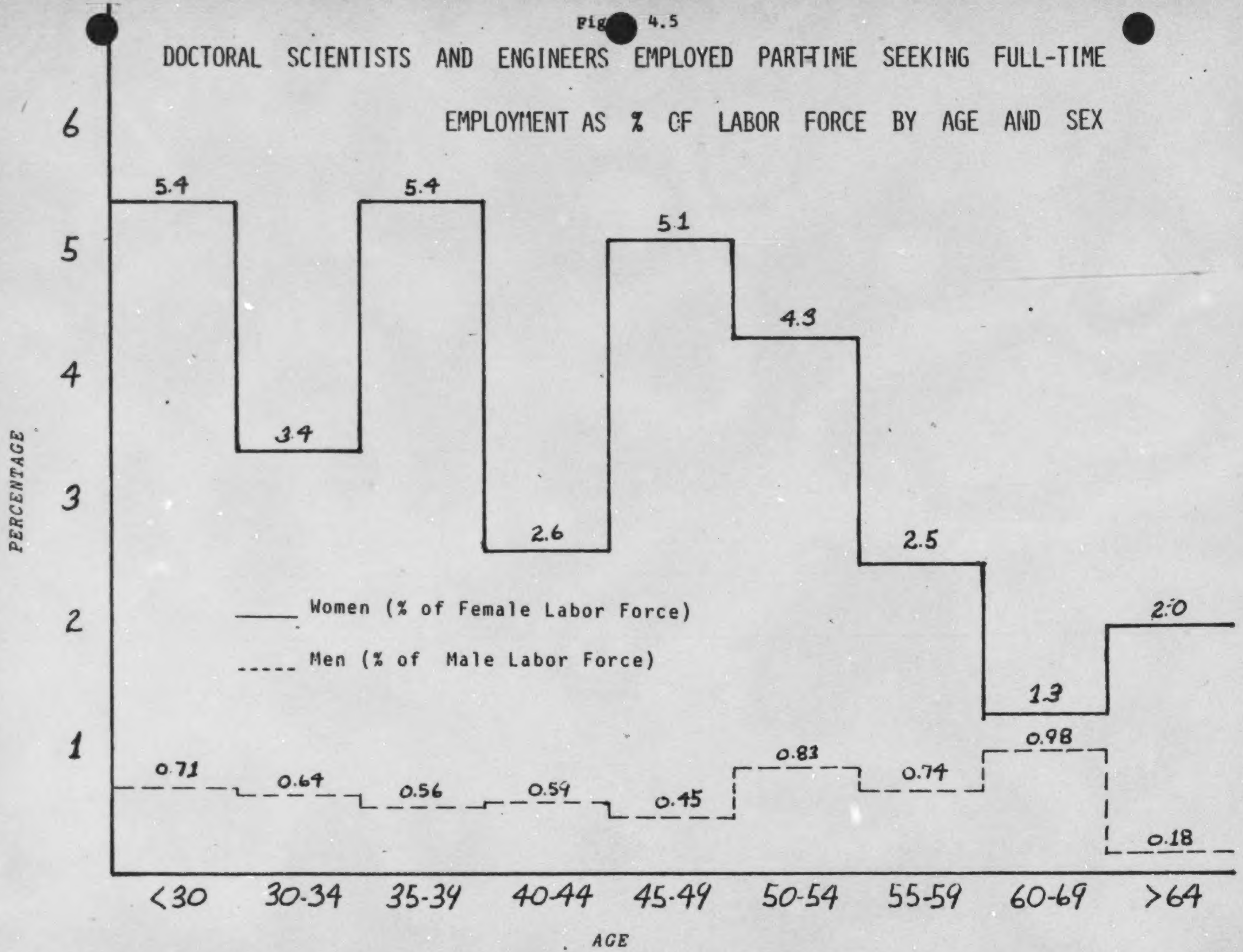
Figure 4.4

PART-TIME EMPLOYED DOCTORAL SCIENTISTS AND ENGINEERS AS % OF LABOR FORCE BY AGE AND SEX



Source: NAS/NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

Figure 4.5



DOCTORAL SCIENTISTS AND ENGINEERS EMPLOYED PART-TIME SEEKING FULL-TIME EMPLOYMENT AS % OF LABOR FORCE BY AGE AND SEX

Source: NAS/NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data)

SECTION 5

Professional Status and Tangible Rewards

In this section the work patterns and the professional status of women scientists will be examined and compared with those of their male counterparts. Where do women scientists work and what kind of work are they doing? How do their ranks and salaries compare?

Women scientists are more likely to work in academic institutions and less likely to work in government and industry than men. Table 5.1 shows the distribution of scientists and engineers by field, sex, and type of employer. This table was computed from the 1970 National Register of Scientific and Technical Personnel[1] and shows the distribution by type of employer of scientists and engineers at all levels of education. It can be seen that 44% of all scientists are in educational institutions, 33% in business and industry, and 10.5% in Federal government. For women the percentages are 62%, 14% and 7.4% respectively. These differences are partly due to the fact that there are proportionately more women in social and biological sciences, fields for which most jobs are to be found in educational institutions. In the biological and social sciences, including psychology, the percentages of men and women in educational institutions are comparable, as can be seen in Table 5.1. In physical and mathematical sciences women are much more likely to be employed by educational institutions than men, and less than half as likely to work in business and industry.

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[1] "American Science Manpower, 1970", NSF 71-45, National Science Foundation, Washington, D.C., 1970.

For doctoral scientists and engineers[2] the pattern is similar, as seen in the Table 5.2. Of all doctoral scientists and engineers 59% work in educational institutions, 22% in business and industry, and 8% in government. For women the figures are 73%, 5% and 5% respectively. The smallness of the percentage of women in business and industry is even more striking than in Table 5.1.

Data on the distribution by type of employer obtained from other surveys in selected fields[3,4,5,6] are presented in Table 5.3 for comparison with

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[2] "Characteristics of Doctoral Scientists and Engineers in the United States, 1973", NSF 75-312-A, National Science Foundation, Washington, D.C., 1975.(This report is based on the NAS-NRC survey of doctoral scientists and engineers, see footnote 2 in section 2).

[3] Cowley, Humpreys, Lynds, Rubin, "Report to the Council of AAS from the Working Group on the Status of Women in Astronomy 1973", Bulletin of the American Astronomical Society, 6,(3) Part II, 1974.

[4] "1974 Report of Chemists' Salaries and Employment Status", Office of Manpower Studies, American Chemical Society, Washington, D.C., June, 1974.

[5] B. M. Vetter and E. L. Babco, "Professional Women and Minorities, a Manpower Resource Service", Scientific Manpower Commission, Washington, D.C., May, 1975. (The data are taken from the table PS-G-4A based on unpublished 1974 data from the American Geological Institute).

[6] C. A. Boneau and J. M. Cuca, "An Overview of Psychologies' Human Resources, Characteristics and Salaries from the 1972 APA Survey", American Psychologist, November, 1974, (See also table SS-P-16 in B. M. Vetter and E. L. Babco, "Professional Women and Minorities, a Manpower Resource Service", Scientific Manpower Commission, Washington, D.C., May, 1975).

Tables 5.1 and 5.2. Since the data in this table were obtained from surveys of different populations and conducted at different times, the numbers in the table are not the same as those in the preceding tables. Yet the overall patterns are similar. Again one observes the preponderance of women in academic institutions, and their relative scarcity in business and industry[7]. However, data on a sample of recent graduates in chemistry[8] (Table 5.4) indicate that this pattern may be changing. More than half of recent women graduates were hired by industry at all degree levels.

Data on the distribution by work activity also show differences between men and women scientists. Women are much more likely to teach and much less likely to work as managers and administrators as compared to men. Table 5.5 shows the distribution of scientists of all educational levels by primary work activity[1]. It is seen that of all scientists 33% are in research, 25% in teaching, and 24% in management or administration. For women scientists the figures are 33%, 38% and 9%. Table 5.6 shows similar data for doctoral scientists and engineers[2] . It shows 33% of all doctoral scientists in research,

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[7] A survey of women engineers found that, in 1972, 62% of women worked in industry, 14% in federal government, and 13% in educational and non-profit institutions; comparison with men engineers was not presented. ("Profile of Woman Engineer", Society of Women Engineers, 345 East 47th Street, New York, NY 10017, 1972)

[8] "1974 Survey Report, Starting Salaries of Chemistry and Chemical Engineering Graduates", Office of Manpower Studies, American Chemical Society, Washington, D.C., 1974.

39% in teaching, and 19% in management and administration. For women the distribution by work activity is 28% in research, 47% in teaching and 9% in management and administration.

The tables also show variations in work activity distribution by field. One can see that about two thirds of mathematical and social doctoral scientists are primarily teachers. In all other fields the proportions of those teaching is much smaller. In almost every field women are more likely to teach than men; the discrepancy is largest in physical sciences. The pattern of much smaller representation of women than men in management and administration is repeated consistently in every field without exception.

Results of other surveys lead to similar conclusions. A 1974 survey of chemists[4] show women as much more likely to teach than men, and about half as likely to work in management. A study of microbiologists[9] assessed the degree of independence felt by men and women microbiologists in their work. This study found that women felt less independence than men, indicating that men are more likely to work in supervisory or managerial capacity.

The difference in status between male and female scientists becomes even more obvious when one looks at salaries. Figure 5.1 shows median annual salaries of scientists at all degree levels[1] by sex and years of professional experience. Figure 5.2 gives salaries of doctoral scientists and engineers by sex and year of doctorate[2]. The two figures are similar. There is an initial salary gap that gets bigger and bigger with time. The largest earnings gap is reached by doctorates after 35-39 years of experience. At this point female salaries are about two thirds of male salaries.

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[9] Kashket, Robbins, Leive and Huang, "Status of Women Microbiologists", Science, 88, 488, February 1974.

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In Figures 5.3 and 5.4 salaries of male and female scientists are compared by field. Figure 5.3 is derived from the post-censal survey data [10] and Figure 5.4 is from the NRC data[2]. The main thing to be observed from these figures is that, while there is some variation by field, male salaries exceed female salaries in every field without exception. The salary differences between men and women are smaller for doctoral scientists than for those with lower degrees. Yet even for doctoral scientists the salary gap is considerable: the salary of a female doctoral scientist is 83% of that of her male colleague[11].

It was seen that the salary gap between men and women scientists cannot be accounted for by years of experience. In fact, the opposite seems to be true: the more experience the bigger the salary gap. Differences in education and in the choice of the scientific field cannot account for the pay gap either. Womens' salaries are lower in every field. Can this salary gap be attributed to other factors, such as the type of work or the type of employer?

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[10] "Demographic, Educational and Professional Characteristics, the 1972 Scientist and Engineer Population Redefined", Volume 1, NSF 75-313, Washington, D.C.

[11] Some caution should be exercised in comparing the data in figures 5.3 and 5.4 since they are derived from two different surveys. While both surveys were conducted at about the same time and both were designed to collect similar data, there are considerable differences in the results. For example, the median salaries of doctoral scientists obtained from the NRC survey are somewhat higher than those from the post-censal survey , as can be seen in the Table 5.7. Other differences are discussed in footnote 4 of section 2.

Figures 5.5 and 5.6 show salaries of men and women doctoral scientists[2] by the type of employer. Similar data by the type of work are shown in the Figure 5.7. Figure 5.5 compares salaries by type of employer, field and sex, Figure 5.6 shows salary comparisons by type of employer, age and sex. It is seen from these figures that median salaries in government and industry are considerably higher than in educational institutions. Comparing by the type of work, Figure 5.7, one sees that salaries for management and administration are the highest and those for teaching are the lowest. When salaries are compared by sex the familiar pattern emerges. For each type of employer, for each type of work, for each field, and for every age, women's salaries are consistantly lower. The salary gap is greatest in industry and smallest in federal government.

Clearly, some of the salary differences between male and female scientists are due to the fact that women are more likely than men to work in educational institutions where the pay is smaller and are less likely to work in industry where salaries are higher. Some of the salary gap can be attributed to the fact that women are very scarce in management positions, where the pay is the highest. Yet the above factors provide only a partial explanation for the salary gap. One is led to conclude that women scientists are paid less than men no matter where they work nor what they do.

Independent studies in several scientific fields confirm these conclusions. Thus, a 1973 survey of the membership of the American Astronomical Society[3] found female astronomers earning about $3,000 less than male astronomers, $15,700 compared to $18,400. A study of women engineers[12] found that in

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[12] "Profile of Woman Engineer", Society of Women Engineers, 345 East 47th Street, New York 10017, 1972; Naomi J. McAfee, "Women in Engineering" New Engineer, March 1973.

1972 after 11 years of experience median salary of women was $14,200, that of men was $16,700. The scarcity of women engineers in management positions (3% of female engineers and 20% of the male ones work in management) may account for some of this salary gap. The same study found that the 1972 starting salaries offered to men and women engineers were comparable: $893 per month for women and $892 for men. A 1971 study of young women in engineering[13] finds that young men and women engineers are quite comparable in the type of work, type of employer and in salary. However, it also finds that women exceed men in professional accomplishments, such as awards, publications and other scientific contributions. These findings are consistent with the pattern described earlier in this section, i.e. a growing salary gap between men and women with increasing years of experience.

The committee on women in psychology also found significant salary differentials between men and women in academic departments[14]. Women earned less than men partly because women were concentrated in lower ranks. Yet when salaries were compared by rank, it was found that men make more than women in most ranks; the highest differential occured at the highest rank. Comparison over three years, 1972 to 1974, showed little improvement in the relative status of women.

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[13] Harold G. Kaufman, "Young Women in Engineering, a Little Bit Better than Men", New Engineer, February 1975

[14] Surveys of Departments of Psychology, 1972 and 1973, American Psychological Association, Committee on Women in Psychology, March 1974; Joan Joesting, "Academic Women Revisited", paper presented at the Convention of the Southeastern Psychological Association, Hollywood, Florida, May2-4 1974.

Chemists' salaries are compared by sex in the Table 5.8 and in Figures 5.8 and 5.9. These data are from the surveys conducted by the American Chemical Society[4,15]. Figure 5.8 gives median salaries of male and female chemists by degree from 1963 to 1974. One observes that for every degree male salaries are higher than female salaries. All salaries increase with time, but the gap between men and women remains approximately constant. It is remarkable that a male chemist with a bachelor's degree has been earning more the a female chemist with a Ph.D. Figure 5.9 compares 1974 full-time salaries of chemists by sex, degree and experience. This figure shows the same pattern as that observed in similar Figures 5.1 and 5.2 for all scientists. Women chemists earn less than men and the salary gap between men and women increases with education and experience. Only B.S. women chemists with two to four years of experience earn salaries comparable to their male counterparts. Table 5.8 shows 1974 full-time chemists' salaries by sex, degree and employer. It is seen that women's salaries lag behind men's salaries in every category; the pay gap is the greatest in industry for chemists with bachelor's and master's degrees. A recent analysis of the 1975 chemists' salaries[16] finds that women chemists, on the average, earn less than three quarters as much as their male colleagues; the differences in the amount of work experience, in academic qualifications, type of employer, or work function cannot fully account for this gap.

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[15] Sharon Johnson, "How to Stop Sex Discrimination", paper presented at the American Chemical Society's 166th Annual Meeting, Chicago, August 27, 1973.

[16] Chemical and Engineering News, p. 33, May 1976.

Salaries of microbiologists[17] are given in Tables 5.9 and 5.10. Table 5.9 shows distribution by type of employer sex and degree level for three consecutive years: 1970, 1971 and 1972; salaries are given for 1970 and 1972. Table 5.10 compares median annual professional income by sex and degree level for the same three years. One sees the same familiar pattern. Women's salaries are consistently lower than men's salaries; there is little to indicate that the relative status of women is improving. Besides salaries, this table presents data on additional income. It shows that additional income of women is about half that of men; moreover a much smaller percentage of women than men earn any additional income. This indicates that salary comparisons do not really tell the whole story. When the total professional income from all sources is compared for men and women the earnings gap widens even more. In order to see whether marriage and family responsibilities might account for women's lower salaries, the salaries of microbiologists were also analyzed by marital status and by number of dependents. It was found that all women, married or not, with children or without, appear to be equally penalized[9].

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[17] Mary Louise Robbins, "Status of Women Microbiologists", ASM News, 37, (2), April 1971; "Employment Rates and Preliminary Salary Data on ASM Membership" ASM News, 38, (4), April 1972; Peter L. Sguros, "Women in Microbiology, a Report of Progress", ASM News, 39, (10), October 1973; Loreta Leive, "Status of Women Microbiologists", ASM News, 37, (3), August 1971; Mary Louise Robbins, "Another Look at the Profile of a Member (with Special Emphasis on the Woman Member))", ASM News, 38, (10), October 1972.

Academic salaries of political scientists[18,19,20] are compared in Table 5.11 by sex for 1970, 1972 and 1974. Again, a salary gap between men and women is seen. It is difficult to compare this gap as a function of time since the population sample seems to be different for surveys conducted in different years. The data on academic salaries for a small sample of political scientists by marital status[18] are presented in Table 5.12. It is seen that though married women earn lower salaries than single women, women who have never been married still make less money than men.

Centra's study of men and women doctorate holders[21] also shows large salary disparities between sexes. He found that in 1973 the median annual income for women doctorates in all science and non-science fields employed full-time was $17,200; for men doctorates it was $21,600. The disparity was largest in physical sciences and social sciences where women earned about a fourth less than men. He found that income disparity is slightest in the government and greatest in private companies. He also found that the disparity between men's and women's incomes becomes greater with years of experience. While Centra's study is not restricted to scientists, his findings on income disparities are in general agreement with those of the other surveys described in this section.

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[18] P. E. Converse and J. M. Converse, "The Status of Women as Students and Professionals in Political Science", PS 4 (3), 328, Summer 1971.

[19] Ada W. Finifter, "The Professional Status of Women Political Scientists", PS, 406, Fall 1973.

[20] "Committee on the Status of Women in the Profession", PS, 319, Summer 1974.

[21] John A. Centra, "Women, Men and Doctorate", Educational Testing Service, Princeton, New Jersey, September 1974.

In a recent study Bayer and Astin[22] analyzed salaries of teaching faculty in both science and non-science fields. The purpose of their study was to assess sex discrimination in academe. To do this they looked at differences in academic rank, tenure and salary between men and women after all the possible nonsexual contributing factors were removed. They compared their results for 1972-73 with those of 1968-69. They concluded that a rank differential remains, though it is smaller than in 1968-69. The salary differential between men and women in higher academic ranks remains about the same in 1972-73 as it was in 1968-69, but the salary difference is wiped out in lower ranks.

A more recent survey[23] by the National Center of Educational Statistics arrived at slightly different conclusions. In this study the 1975 salaries of full-time faculty members (on academic year contracts) at colleges and universities were compared with those of 1974. It was found that in all fields (both science and non-science) women's salaries were $14,566 and men's salaries were $18,892, as shown in the Table 5.13. Women's salaries were lower than men's for all ranks. The salary difference is smallest for assistant professors, about $800, and largest for full professors, about $3,000. In addition, it was found that from 1974 to 1975 men's salaries increased by 6.3%, while women's by only 5.8%. This study also compared the representation of women on faculties for the two years: 1974 and 1975. It was found that the percentage of women faculty on academic year contracts remained even at 24% in

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[22] A. E. Bayer and H. S. Astin, "Progress in the Elimination of Sex Discrimination in Academe: Have Antibias Regulations and 'Good Faith' Helped?", to be published.

[23] Chemical and Engineering News, 3, February 9, 1976.

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1975 compared with the previous year. The percentage of women declined, however, in professor, associate professor and instructor ranks. The percentage of women increased in assistant professor, lecturer, and undesignated positions. The overall implication of this survey is that the relative status of women in academic institutions is getting worse rather than better in spite of "affirmative action".

Academic salaries of doctoral scientists and engineers are compared by sex, rank and type of institution in the Table 5.14[24]. This table also shows the distribution of men and women by rank. It is seen that for men the overall salaries are higher in four year colleges and universities than those in junior colleges, $19,500 versus $18,700. Women's median salaries for all ranks are lower than men's and are the same for both types of institution, $17,100. Comparing by rank, one sees that at colleges and universities the salary gap is about $3,000 at the professor level and $1,000 at the assistant professor level. It is remarkable that while these numbers are based on the 1973 data, they are almost the same as the ones found in the 1975 study discussed in the previous paragraph. At junior colleges women's salaries are comparatively better. Comparing by rank, it is seen that at the professor level women earn the same salary as men, and at the instructor level women's salaries are higher; but women still lag behind men in the assistant and associate professor ranks.

The distribution of men and women doctorates by academic rank, shown in the same table, provides further insight into their relative status. It is seen that at both types of institution women are heavily concentrated in lower ranks. Women are twice as likely as men to work in junior colleges: 4.6% of women doctoral scientists and engineers and 2.1% of men are in these two year institutions. In colleges and universities women are almost twice as likely as men to hold the rank of assistant professor, instructor or lecturer, while men are twice as likely to be full professors. At junior colleges a smaller proportion of both men and women hold the rank of professor and a larger proportion are instructors. More than half of women and about 40% of men are assistant professors or instructors.

What is the reason for women's disproportionate concentration in lower academic ranks? In an attempt to answer this question consider Figure 5.10. This figure shows the age distribution of doctoral scientists and engineers[24] in academic institutions by rank and sex. It is seen that for every rank women's median age is higher than men's. For assistant professors this age difference is two years, six years for associate professors, four years for full professors and three years for instructors, lecturers and other. These age differences are larger than one and a half years found for doctoral scientists and engineers as a whole (see section two of this paper). Further inspection of this figure leads to the following observations.

For assistant professors the age distributions are similar for both sexes up to about 35 years. For older ages there are proportionately more women than men. The curves for associate professors exhibit the most pronounced differences between men and women. The curve for males has a sharp peak for the 35-39 age group and declines rapidly with age. For women associate professors the curve is much flatter and peaks at an older age, between 40 and 49 years. For professors, the female curve is again much flatter than the male one, and its peak occurs for older ages.

These observations can be interpreted as follows: At the assistant professor level women and men start out about the same; but after a few years all similarity ends. It takes men about five years to get promoted to the associate professor rank and another five to that of a full professor. Women stay much longer in the lower ranks, their promotions are slower, and only a few make it to the top rank of professor. The previously discussed salary data indicate that of the few who make it to the top rank, even a smaller number attain salaries comparable to their male collegues.

Another indication of the relative status of doctoral scientists and engineers is the extent of support by government funds. These data were also available from the NRC survey[24], and are shown in Tables 5.15 and 5.16. Table 5.15 shows government support by field for all types of institution, and separately for academic institutions. It is seen that more men than women doctoral scientists and engineers receive government support; 47.2% of men and 40.9% of women are supported by government funds. This pattern is repeated consistently in all fields of science. The discrepancy is largest in mathematical sciences, 39% of men and 19% of women in this field receive government support. The difference is smallest in life sciences, where 60% of men and 59% of women receive government support.

In academic institutions 46% of men doctoral scientists and engineers and 36% of women receive government support (Table 5.15). Comparison by field shows that women are supported to a lesser extent than men in most fields; the exceptions are earth science and atmospheric science. It is interesting that the smallest discrepancy occurs in fields where women are most numerous: life science, social science and psychology. The discrepancy is the biggest in the mathematical and physical sciences.

Table 5.16 shows support by government funds by academic rank and sex. In each rank a larger fraction of men than women are supported by government funds. Women supported by government funds are almost three times as likely as men to hold a low academic rank: 29% of government supported women and 10% of men hold the rank of instructor, lecturer or other. The opposite is true for high academic ranks: 67% of men and 37% of women supported by government funds hold the rank of associate professor or professor. This phenomenon can be partly, but not totally explained by the overall distribution of men and women over the academic ranks. The two distributions by rank, the distribution of respondents and the distribution of supported persons are shown in the Table 5.16 for comparison.

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[24] NAS-NRC Survey of Doctoral Scientists and Engineers, 1973 (unpublished data).

How is one to interpret the meaning of these data? There are two ways to look at it. On the one hand, support by government funds can mean prestige and independence for the faculty member, especially if she/he is the principal investigator or a project director of a funded project. It often provides additional income, like summer salaries, travel money for conferences and other fringe benefits. This is more likely to occur for faculty members in higher academic ranks. On the other hand, government support may mean that the supported person lives on "soft money", and her/his job can disappear with the loss of funding. This would be true for faculty members holding ranks outside of the regular tenure track, such as instructor, lecturer or other. It is tempting to conlude from the data in Table 5.16 that for women support by government funds means support by "soft money", while prestige and independence provided by government funding is more likely to accrue to men than to women.

Distribution by rank of academic scientists had been investigated in many independent studies[3,14,17,19,25-30]. These studies were mostly performed by

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[25] "Women in Physics", Bulletin of the American Physical Society, p. 740, June, 1972.

[26] Cathleen S. Morawetz, "Women in Mathematics", Notices of the American Mathematical Society, p. 131, April 1973.

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women's committees of professional associations in several different fields. Overall distributions by rank were compared for men and women. In addition, in some of these, different types of institutions were compared. Several studies were repeated in later years. The results of these surveys are summarized in Table 5.17. This table shows, not surprisingly, that unlike men, women tend to be concentrated in lower ranks. Women's tendency to populate the lowest ranks increases and their overall representation decreases with the prestige of the institution. This pattern is seen in the data for physics, economics, and political science.

Comparison over the years covered in the table shows a slight increase in the representation of women on faculties of colleges and universities. This reflects the recent increase in the number of women entering the professions. Thus, in psychology the percentage of women full-time faculty members in graduate departments increased from 14.5% to 15.7% from 1972 to 1973; in anthropology from 1971-72 to 1973-74 the percentage of faculty women changed

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[27] 1971-72 and 1973-74 unpublished data from the Committee on the Status of Women in Anthropology; see also AAA Newsletter, 14 (2), 1973.

[28] Annual Report of the Committee on the Status of Women in the Economics Profession, 1972 and 1974, AEA (unpublished).

[29] "Women in Political Science", p. 53, APSA, Washington, D,C,, 1971; 1972-73 and 1974-75 Surveys of Departments, American Political Science Association; Ada W. Finifter, "The Professional Status of Women Political Scientists: Some Current Data", PS, p. 406, Fall 1973.

[30] "The Status of Women in Sociology, 1968-72", The American Sociological Association, Washington, D.C., 1973.

from 19.8% to 21.3%, in economics the corresponding change was from 6.4% to 7%. In political science, from 1969 to 1974 the proportion of women full-time faculty members increased from 8.4% to 10.0%; and in sociology the increase from 1970 to 1972 was from 9.3% to 12.2%. However, a closer examination of the data in table 5.17 will reveal that no significant change in the distribution of women over the ranks has occurred over the years.

A slight percentage increase of women faculty was also found by Bayer[31] over a similar time interval. Comparing the results of two similar surveys of the teaching faculty in academe, he found that the proportion of faculty who were women increased from 19.1% in 1968-69 to 20.0% in 1972-73. While Bayer's results are for all faculty, both in science and non-science fields, his findings are consistent with those for scientists discussed above. One should recall, however, that more recent data[23], for 1974 and 1975, show no change in the overall proportion of women on faculties of colleges and universities.

The unusually low representation of women in prestigious universities was also noted in chemistry. It was found[32] that there were no women on the faculty of the top five[33] departments in chemistry, which grant 6.9% of their Ph.D.'s to women. The same study found that among 172 schools with a total of

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[31] Alan E. Bayer, "Teaching Faculty in Academe: 1972-73", ACE Research Reports 8 (2), August 1973; Alan E. Bayer, College and University Faculty: A Statistical Description", ACE Research Reports 5 (5), June 1970.

[32] Chepelinsky, Franchetti-Sicignano, Lowe, Tooney, Verbugge, "Women in Chemistry, Part of the 51% Minority", Science for the People, Jamaica Plain, Massachusetts, July 1972.

[33] These are Harvard, Cal. Tech., Berkeley, Stanford and MIT.

3,925 Ph.D. faculty members, only 90 were women, or 2.3% Of these 43% were of subprofessional rank (instructor, research associate, etc.). A more recent survey[34] of 188 Ph.D. granting departments resulted in similar findings. Women were found to constitute 2.6% of the full-time faculty at all institutions, but only 0.5% of the faculty at the top rated[35] institutions.

The status of academic women was also considered in a number of campus reports. About sixty such reports, undertaken by individuals and groups both on and off campus, were studies by Robinson[36]. Her publications contain an annotated bibliography of campus reports and an analysis and summary of their findings. She concludes that these reports confirm the inferior status of academic women, using criteria such as rank, salary, promotion and involvement in administration. It was found that women are often in positions which do not provide for their inclusion in the regular workings of the academic community.

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[34] Chemical and Engineering News, p. 40, April 7, 1975.

[35] K. D. Roose and C. J. Anderson, "A Rating of Graduate Programs", American Council on Education, Washington, D.C., 1970.

[36] Lora H. Robinson, "The Status of Academic Women", Eric Clearing House on Higher Education, Washington, D.C., April 1971; Lora H. Robinson, "Institutional Analysis of Sex Discrimination: A review and Annotated Bibliography", ERIC Clearing House on Higher Education, Washington, D.C., June 1973; Lora H. Robinson, "Institutional Variation in the Status of Academic Women" in the book edited by Alice Rossi and Ann Calderwood "Academic Women on the Move", New York, 1973.

Analysis by academic rank showed that women constitute a smaller proportion of each ascending rank and occupy a higher percentage of marginal, non-ladder, temporary, or fringe positions. When promotion rates were compared by sex, it was found that women advanced more slowly and remained longer in lower ranks. Salary studies lead to the overwhelming conclusion that women earn less than men with the same qualifications. women were found to be very scarce in academic administration and the higher the position the fewer women are found. Oltman[37] reached similar conclusions in her study of women in administrative positions.

On the whole, the data in this section present a rather dismal picture of the status of women in the scientific professions. Moreover, there is little to indicate that the status of women scientists has improved over the recent years.

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[37] Ruth M. Oltman, "Survey on Women in Academe", American Association of University Women, Washington, D.C., December 1970.

Table 5.1

PERCENTAGE DISTRIBUTION OF SCIENTISTS AND ENGINEERS BY FIELD, SEX AND TYPE OF EMPLOYER
(All degree levels)

	Business/Industry		Educational Institutions		Non-profit Organizations		Federal Government		Other		Number Responding Total	Number of Women Responding
	Total%*	Women%*	Total%	Women%	Total%	Women%	Total%	Women%	Total%	Women%		
All Fields	32.8	14.3	43.8	61.7	3.7	7.2	10.5	7.4	9.2	9.4	297,416	25,668
Chemistry	61.5	33.7	24.0	45.0	2.6	7.1	6.1	8.5	5.8	5.8	82,697	5,531
Physics	28.9	11.4	53.3	73.1	2.7	3.6	11.5	9.7	3.6	2.2	33,927	1,069
Earth & Marine Sc.	43.8	11.8	28.7	55.0	1.1	4.0	13.4	18.5	13.0	10.7	22,764	720
Atmospheric & Space Sc.	12.3	10.0	16.3	40.0	1.5	2.2	32.9	33.3	37.0	14.4	6,244	90
Mathematics	60.2	8.9	27.3	82.6	2.1	1.2	5.3	4.8	5.0	2.6	23,267	2,337
Statistics	27.6	19.2	38.3	34.0	4.5	8.1	21.4	26.9	8.3	11.8	2,804	297
Computer Science	67.9	61.5	14.6	17.8	3.6	5.1	8.0	9.9	5.8	5.7	10,988	1,096
Biological Sc.	10.6	5.7	63.0	71.2	6.5	9.1	10.7	7.2	9.2	6.8	45,702	5,574
Agricultural Sc.	16.8	11.1	23.2	35.6	1.4	8.9	37.3	20.0	21.3	24.4	15,342	45
Psychology	7.8	3.6	59.4	62.1	8.3	9.9	6.2	4.1	18.4	20.3	25,028	5,672
Economics	14.3	11.4	61.4	58.2	4.1	5.0	11.8	14.5	8.4	10.9	12,779	696
Sociology	1.9	2.0	83.0	76.9	5.1	7.3	3.3	4.6	6.8	9.2	6,835	1,403
Anthropology	0.9	0.4	85.5	82.8	3.0	3.4	2.3	1.7	8.3	11.6	1,251	232
Political Sc.	1.9	2.4	82.1	80.4	3.6	4.0	5.7	7.7	6.6	5.5	6,085	545
Linguistics	3.2	3.0	83.2	80.3	7.4	9.1	3.1	2.5	3.1	5.0	1,703	361

* Total means both sexes, i.e. for all fields 32.8% of both sexes and 14.3% of women are in business or industry

Source: "American Science Manpower, 1970", National Science Foundation, Washington, D.C., 1970.

Table 5.2

PERCENTAGE DISTRIBUTION OF DOCTORAL SCIENTISTS AND ENGINEERS BY FIELD, SEX AND TYPE OF EMPLOYER

	Business and Industry		Educational Institutions		Hospitals, Clinics		Non-Profit		Federal Government		Other		Total Number Responding to one of the Categories	
	Total%*	Women%*	Total%	Women%	Total%	Women%	Total%	Women%	Total%	Women%	Total%	Women%	Total	Women
All Fields	22.4	5.3	59.4	72.8	2.6	7.0	3.5	4.3	7.9	5.0	4.2	5.6	223,214	16,837
Physical Science	39.7	17.0	45.5	69.1	0.6	1.5	3.4	3.5	8.5	6.6	2.2	1.0	48,391	1,819
Chemistry	50.3	19.1	39.1	69.4	0.8	1.9	2.6	3.3	5.4	4.4	1.9	2.1	30,387	1,401
Physics/Astronomy	21.8	10.3	56.5	68.2	0.4	0.2	4.8	4.3	13.8	14.1	2.8	2.9	18,004	418
Mathematical Science	6.8	3.3	86.1	92.0	-	-	1.5	1.2	4.1	1.4	1.4	1.9	12,424	805
Mathematics	6.3	3.2	87.6	94.1	-	-	1.6	0.8	3.5	0.4	1.1	1.5	10,954	728
Statistics	11.2	6.5	75.1	72.7	-	-	1.4	5.2	8.3	10.4	4.1	5.2	1,470	77
Computer Science	36.1	33.3	51.8	52.9	0.8	-	3.8	2.3	4.1	8.1	3.4	3.4	2,908	87
Environmental Science	19.5	10.3	51.0	65.7	-	-	4.4	1.5	18.9	11.8	6.3	10.7	10,424	271
Earth Science	22.4	10.5	49.9	63.2	-	-	3.4	0.4	17.9	13.4	6.4	11.5	8,628	209
Oceanography	6.6	6.7	61.8	80.0	-	-	9.6	-	15.5	4.4	6.5	8.9	1,122	45
Atmospheric Science	3.4	17.6	46.7	58.8	-	-	8.2	5.9	37.2	11.8	4.4	5.9	674	17
Engineers	48.6	43.7	36.5	35.6	0.2	-	3.6	4.4	7.5	13.3	3.5	3.0	35,666	135
Life Science	11.7	4.7	68.2	74.8	3.3	4.5	3.1	4.3	10.0	7.4	3.8	4.3	58,389	5,964
Biological Science	8.6	4.0	73.0	77.2	2.6	3.3	3.8	4.4	9.0	7.4	3.0	3.9	36,901	4,801
Agricultural Science	16.8	20.2	63.2	66.1	-	-	1.0	2.4	16.5	9.7	2.5	1.6	10,894	124
Medical Science	17.2	6.2	56.4	65.1	9.2	10.8	2.7	4.2	6.9	7.2	7.6	6.5	10,594	1,039
Psychology	5.7	2.2	62.7	62.5	13.2	18.2	4.7	4.7	3.8	2.6	10.0	9.8	25,464	4,784
Social Science	4.2	1.7	82.5	85.3	0.1	0.1	4.0	5.3	4.9	3.2	4.2	4.4	29,421	2,966
Economics	9.1	4.4	73.2	76.6	-	-	4.0	6.8	7.6	9.3	6.1	2.8	8,580	496
Sociol./Anthrop.	0.9	-	92.4	92.9	0.1	-	3.2	3.7	1.2	.5	2.1	2.9	6,692	1,232
Other Soc. Sci.	2.8	2.3	83.3	81.2	0.2	0.2	4.5	6.2	5.0	3.6	4.2	6.5	14,149	1,238
No Report	7.9	33.3	79.5	66.7	6.3	-	1.6	-	-	-	4.7	-	127	6

*Total means both sexes, i.e. 22.4% of both sexes and 5.3% of women are in business and industry.

Source: "Characteristics of Doctoral Scientists and Engineers in the United States, 1973", NSF-312-A, National Science Foundation, Washington, D.C., 1975 (This report is based on the NAS-NRC survey of doctoral scientists and engineers).

Table 5.3

PERCENTAGE DISTRIBUTION OF SCIENTISTS IN SELECTED FIELDS BY SEX, DEGREE AND TYPE OF EMPLOYER

	Business/ Industry		Educational Institutions		Government		Other			
Field	Total%	Women%	Total%	Women%	Total%	Women%	Total%	Women%	Total No.	No. of Women
Astronomy[1]										
All Degrees	5.0	2.0	64.0	77.0	18.0	10.0	13.0	10.0	559	49
Chemistry[2]										
All Degrees	59.9	40.3	23.0	31.0	10.7	16.3	6.4	12.4		
Ph.D.	48.9	18.7	33.7	53.4	9.0	14.6	6.3	13.2		
Geoscience[3]										
All Degrees	42.1	18.5	30.2	52.0	15.2	25.9	12.5	3.6	38,000	1,900
Psychology[4]										
Master's	6.0	1.7	49.1	58.1	8.8	6.2	36.1	34.0	4,909	1,736
Doctoral	2.4	0.8	63.5	63.3	4.1	3.6	30.0	32.5	19,610	3,614

[1] Cowley, Humpreys, Lynds, Rubin, "Report to the Council of AAS from the Working Group on the Status of Women in Astronomy 1973", Bulletin of the American Astronomical Society, 6,(3) Part II, 1974.

[2] "1974 Report of Chemists' Salaries and Employment Status", Office of Manpower Studies, American Chemical Society, Washington, D.C., June, 1974.

[3] B. M. Vetter and E. L. Babco, "Professional Women and Minorities, a Manpower Resource Service", Scientific Manpower Commission, Washington, D.C., May, 1975. (The data are taken from the table PS-G-4A based on unpublished 1974 data from the American Geological Institute).

[4] C. A. Boneau and J. M. Cuca, "An Overview of Psychologies' Human Resources, Characteristics and Salaries from the 1972 APA Survey", American Psychologist, November, 1974, (See also table SS-P-16 in B. M. Vetter and E. L. Babco, "Professional Women and Minorities, a Manpower Resource Service", Scientific Manpower Commission, Washington, D.C., May, 1975)

Table 5.4

INEXPERIENCED FULL-TIME EMPLOYED CHEMISTS BY SEX, DEGREE AND TYPE OF EMPLOYER[1]

	Business/ Industry		College/ University		Government		Other		All Employed		Median Salary in $	
Degree	Total no.	Women no.	Total no.	Women no.	Total no.	Women no.	Total no.	Women no.	Total no.	Women no.	Total	Women
Bachelor's	318	88	37	14	36	6	71	28	462	136	9,900	10,000
Master's	67	12	5	2	3	0	15	5	90	19	11,800	11,300
Ph.D.	115	7	31	8	8	0	5	0	159	15	16,200	13,000

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[1] "1974 Survey Report, Starting Salaries of Chemistry and Chemical Engineering Graduates", Office of Manpower Studies, American Chemical Society, Washington, D.C., 1974. The data are derived from a sample selected from recent graduates in chemistry.

Table 5.5

PRIMARY WORK ACTIVITY OF SCIENTISTS AND ENGINEERS BY FIELD AND SEX
PERCENTAGE DISTRIBUTION

	Research/ Development		Management/ Administration		Teaching		Other		Number Reporting	
	% of Total	% of Women	% of Total	% of Women	% of Total	% of Women	% of Total	% of Women	Total	Women
All Fields	33.3	33.2	23.6	8.7	24.8	38.1	18.3	20.0	291,472	25,250
Chemistry	38.4	43.6	26.4	7.1	12.6	25.9	22.6	23.5	81,242	5,421
Physics	52.8	37.9	16.4	3.5	25.3	48.8	5.4	9.8	33,226	1,045
Earth & Marine Science	17.8	25.0	18.6	5.7	20.7	40.1	42.9	29.2	22,092	705
Atmo. & Space Science	20.2	35.6	28.9	9.2	7.7	12.6	43.2	42.5	6,073	87
Mathematics	21.0	9.1	20.9	5.9	46.5	76.1	11.6	8.9	22,788	2,301
Statistics	27.9	30.6	20.8	13.7	21.1	15.1	30.2	40.5	2,746	291
Computer Science	37.7	40.9	29.9	9.4	4.0	2.9	28.4	46.8	10,796	1,072
Biological Science	41.6	39.6	18.3	7.6	31.8	43.9	8.3	8.9	44,720	5,497
Agricultural Science	23.0	26.7	59.1	31.1	8.7	17.8	9.3	4.4	14,995	45
Psychology	24.7	31.6	19.9	11.4	27.5	24.7	27.8	32.3	24,718	5,601
Economics	22.0	27.2	23.5	13.0	42.3	45.3	12.3	14.6	12,510	687
Sociology	21.2	25.1	15.7	13.1	58.3	54.8	4.8	6.9	6,7[illegible]5	1,386
Anthropology	23.1	22.8	12.2	6.1	60.5	64.0	4.3	7.0	1,222	228
Political Science	11.4	12.9	17.9	11.4	63.5	65.1	7.2	10.6	5,996	536
Linguistics	17.1	17.8	13.0	7.2	61.3	63.8	8.7	11.2	1,653	348

Source: "American Science Manpower, 1970", NSF 71-45, National Science Foundation, Washington, D.C., 1970.

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Table 5.6

PERCENTAGE DISTRIBUTION OF DOCTORAL SCIENTISTS AND ENGINEERS BY FIELD, SEX AND PRIMARY WORK ACTIVITY

	Research, Development		Management, Administration		Teaching		Other		Total No. Employed and Reporting Work Activity	
Field	Men %	Women %	Men %	Women %	Men %	Women %	Men %	Women %	Men	Women
All Fields	33.0	27.9	19.2	9.1	38.8	46.7	9.1	16.3	210,840	16,180
Phys. Science	42.6	33.6	20.8	8.4	30.8	48.5	5.8	9.5	46,349	1,910
Chemistry	39.6	31.4	24.6	8.7	28.6	50.0	7.3	10.0	28,913	1,374
Physics/Astron.	47.6	41.2	14.5	7.3	34.5	43.4	3.4	8.1	17,436	396
Math.Science	20.3	8.9	7.7	4.2	69.2	81.4	2.8	5.5	11,900	778
Mathematics	20.3	7.2	7.2	4.2	70.4	84.3	2.0	4.2	10,468	706
Statistics	20.7	25.0*	10.8	4.2*	60.0	52.8*	8.6	18.1*	1,432	77
Computer Science	37.2	50.0*	22.5	5.0*	34.7	35.0*	5.7	10.0*	2,807	80
Environmental Sc.	35.9	46.6	23.6	6.3	32.8	33.6	7.7	13.4	9,791	253
Earth Sc.	33.4	39.9*	23.1	6.9*	34.7	37.0*	8.8	16.3*	8,079	203
Oceanography	48.0	75.8*	24.9	-	23.1	24.2*	4.0	-	1,047	33
Atmospheric Sc.	46.9	70.6*	27.8	11.8*	25.3	11.8*	-	5.9*	665	17
Engineers	38.4	48.9	27.8	16.5	26.1	28.6	7.6	13.5	34,314	133
Life Science	42.4	48.4	16.4	6.9	33.7	38.1	7.5	6.6	53,949	5,684
Biological Sc.	44.7	49.8	11.7	5.1	39.6	40.8	4.0	4.3	34,538	4,610
Agric. Sc.	45.2	61.3*	22.7	5.4*	20.5	24.3*	11.6	13.5*	9,843	111
Medic. Sc.	31.4	40.7	26.9	15.7	25.8	26.8	15.9	16.8	9,568	966
Psychology	12.6	10.6	17.8	12.1	40.4	38.2	29.2	39.0	23,698	4,622
Soc. Science	13.3	13.9	15.2	10.4	65.5	69.1	6.0	6.6	27,923	2,850
Economics	17.6	21.0	17.7	15.4	57.2	56.8	7.6	6.7	8,224	461
Socio./Anthrop.	15.2	14.7	10.6	6.8	72.0	75.2	2.3	3.3	6,392	1,183
Other Soc. Sc.	9.8	10.4	16.0	11.9	67.4	67.9	6.8	9.8	13,307	1,206
No Report	1.8*	28.6*	31.2*	-	51.4*	42.9*	15.6*	28.6*	109*	7*

* Indicates a very small sample size.

Source: "Characteristics of Doctoral Scientists and Engineers in the United States, 1973", NSF-312-A, National Science Foundation, Washington, D.C., 1975 (This report is based on the NAS-NRC survey of doctoral scientists and engineers)

Table 5.7

1972 MEDIAN SALARIES OF DOCTORAL SCIENTISTS AND ENGINEERS BY FIELD (COMPARISON OF THE POST-CENSAL SURVEY WITH THE NRC SURVEY)

	Post-Censal Survey Salary in $	NRC Survey Salary in $
Engineers	20,600	22,500
Mathematical specialists	18,700	19,300
Computer specialists	19,100	22,100
Operations research analysts	22,400	
Physical scientists	19,500	21,200
Life scientists	18,500	20,000
Psychologists	19,100	20,200
Social scientists	19,800	20,400

Sources: "The 1972 Scientist and Engineer Population Redefined", Science Resources Studies Highlights, NSF 75-305, April 11, 1975, Washington D.C.

1973 NAS-NRC Survey of Doctoral Scientists and Engineers.

Table 5.8

1974 FULL-TIME CHEMISTS' SALARIES BY SEX, DEGREE AND EMPLOYER (IN THOUSANDS OF DOLLARS)

	Bachelors		Masters		Doctors	
	men	women	men	women	men	women
Business/Industry	18.0	13.2	20.2	14.4	23.4	21.0
Self-Employed	15.1	na	22.0	na	25.0	na
Educational institutions	11.5	9.0	14.0	11.0	17.5	15.0
Government	18.7	15.2	19.5	15.0	24.0	20.9
Non-Profit Institutions*	15.8	11.0	16.3	12.1	21.0	17.0
Other	14.7	na	17.9	na	21.2	na
All Employers	18.0	13.0	19.0	13.5	22.0	16.8

* Includes hospital and independent laboratory.
na - not available

Source: "1974 Report of Chemists' Salaries and Employment Status", Office of Manpower Studies, American Chemical Society, Washington, D.C., June 1974.

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Table 5.9

MICROBIOLOGISTS BY TYPE OF EMPLOYER, SEX, DEGREE, SALARY AND YEAR

Type of Employer and Year	BS/BA		MS/MA		PhD/ScD		Salary, All Degrees (Thousands of Dollars)	
	M	F	M	F	M	F	M	F
1970[1]								
Educational Institutions	24.5%	21.7%	31.3%	42.8%	58.1%	66.2%	15.0	10.0
Private Industry	32.2	20.4	28.7	9.9	16.1	5.4	17.0	12.0
Government	25.2	25.2	22.7	19.0	16.0	12.4	17.0	12.0
Clinical Laboratory	13.0	29.8	9.5	19.1	3.3	4.9	14.0	11.0
1971[2]								
Educational Institutions	20.7	17.3	30.2	39.6	58.9	66.1		
Private Industry	31.2	18.0	24.0	11.1	15.2	4.6		
Government	24.8	23.8	26.8	19.0	16.9	13.6		
Clinical Laboratory	17.5	38.5	13.3	21.2	4.1	7.0		
1972[3] *								
Educational Institutions	23.0(7.5)	21.7(9.0)	32.2(10.0)	36.2(10.0)	58.0(17.5)	66.1(14.0)		
Private Industry	32.5(13.2)	20.4(11.5)	25.9(15.0)	10.8(12.0)	15.3(20.6)	5.6(18.0)		
Government	22.8(14.0)	24.6(12.0)	24.7(15.0)	20.6(13.6)	16.6(21.1)	12.4(19.3)		
Clinical Laboratory	16.0(11.0)	29.4(10.4)	10.2(13.5)	22.9(11.5)	4.3(19.0)	4.7(16.0)		

*Numbers in parentheses are salaries in thousands of dollars

[1] Loretta Leive, "Status of Women Microbiologists", ASM News, 37 (3), August 1971

[2] Mary Louise Robbins, "Another Look at the Profile of a Member (with a Special Emphasis on the Woman Member)", ASM News, 38, (10), October 1972.

[3] Peter L. Sguros, "Women in Microbiology, a Report of Progress", ASM News, 39, (10), October 1973.

Table 5.10

MICROBIOLOGISTS' MEDIAN ANNUAL PROFESSIONAL INCOME BY SEX, DEGREE AND YEAR (IN THOUSANDS OF DOLLARS)

		1970[1]		1971[2]		1972[3]	
Sex	Degree	Basic Salary	Additional Income*	Basic Salary	Additional Income*	Basic Salary	Additional Income*
Men	BS/BA	11.0	1.8(11.7)	12.0	2.0(11.9)	12.0	2.0(47)
	MS/MA	12.0	1.6(13.1)	12.5	2.0(17.2)	14.0	2.0(49)
	PhD/ScD	17.5	1.7(24.3)	18.0	1.5(25.2)	18.7	1.8(68)
Women	BS/BA	10.0	0.9(5.9)	10.0	0.6(6.8)	11.0	1.0(28)
	MS/MA	10.4	1.8(6.5)	11.0	0.5(8.0)	11.6	0.8(48)
	PhD/ScD	13.3	1.3(12.4)	14.0	1.0(13.8)	15.0	1.2(61)

* Figures in parentheses are percentages of those receiving additional income.

[1] Mary Louise Robbins, "Status of Women Microbiologists", ASM News, 37, (2), April 1971.

[2] "Employment Rates and Preliminary Salary Data on ASM Membership", ASM News, 38, (4), April 1972.

[3] Peter L. Sguros, "Women in Microbiology, a Report of Progress", ASM News, 39, (10), October 1973.

Table 5.11

FULL-TIME ACADEMIC SALARIES OF POLITICAL SCIENTISTS BY SEX AND YEAR (IN THOUSANDS OF DOLLARS)

	Men		Women	
Year	Salary	Number	Salary	Number
1970[1]	16.6	97*	11.9	178*
1972[2]	15.2	4338	12.7	470
1974[3]	14.8	4275	12.8	418

* This number represents the sample size rather than the actual number of men and women.

[1] P. E. Converse and J. E. Converse, "The Status of Women as Students and Professionals in Political Science", PS 4 (3), 328, Summer 1971.

[2] Ada W. Finifter, "The Professional Status of Women Political Scientists", PS, 406, Fall 1973.

[3] Committee on the Status of Women in the Profession", PS, 319, Summer 1974.

Table 5.12

ACADEMIC SALARIES OF POLITICAL SCIENTISTS BY SEX AND MARITAL STATUS[1] (IN THOUSANDS OF DOLLARS)

	Women				Men	
	Ever Married		Never Married		Married and Unmarried	
	Salary	Number	Salary	Number	Salary	Number
Doctorates	11.7	95	14.7	44	17.0	81
Non-Doctorates	9.1	na	9.1	10	14.7	16

na - not available

[1] P.E. Converse and J.E. Converse, "The Status of Women as Students and Professionals in Political Science", PS 4 (3), 328, Summer 1971.

Table 5.13

1975 ACADEMIC FULL-TIME SALARIES
(ACADEMIC YEAR CONTRACTS)

	men	women
Professors	$24,448	$21,465
Associate professors	17,809	16,788
Assistant professors	14,625	13,872
Instructors	11,909	11,259
Lecturers	13,921	12,339
Undesignated rank	11,901	10,365
TOTAL	$18,862	$14,556

Source: Department of Health Education and Welfare (reported in Chemical and Engineering News, February 9, 1976).

Table 5.14

DOCTORAL SCIENTISTS AND ENGINEERS
MEDIAN ANNUAL ACADEMIC SALARIES AND DISTRIBUTION BY RANK, TYPE OF INSTITUTION AND SEX
(SALARIES ARE IN THOUSANDS OF DOLLARS)

	MEDIAN ANNUAL SALARIES				PERCENTAGE DISTRIBUTION			
	Four Year College or University		Junior College		Four Year College or University		Junior College	
Academic Rank	men	women	men	women	men	women	men	women
Total*	19.5	17.1	18.7	17.1	111,293	9,177	2,381	441
Professor	24.4	21.6	22.6	22.6	41.2	24.0	29.2	18.9
Associate Professor	18.5	17.8	18.2	17.3	29.2	29.1	20.7	18.9
Assistant Professor	16.2	15.2	14.9	14.3	24.6	36.4	23.6	34.6
Instructor	13.0	12.8	16.4	17.3	0.6	1.5	14.3	18.6
Lecturer	16.3	14.5	na	na	0.4	1.4	0.2	na
Other	17.0	13.8	20.4	na	4.0	7.6	12.0	9.0
No report	19.3	12.4	20.4	na				

* "Total" means median salary for all ranks in the first four columns and the total number of all men or women in the last four columns.

na - not available

Source: NAS-NRC Roster of Doctoral Scientists and Engineers, 1973 (Unpublished Data).

Table 5.15

PERCENTAGE BY FIELD OF DOCTORAL SCIENTISTS AND ENGINEERS SUPPORTED BY GOVERNMENT FUNDS

	All Types of Employer		Educational Institutions	
Field	men	women	men	women
All Fields	47.2%	40.9%	46.1%	35.6%
Physical Science	42.6	35.5	47.0	28.2
Chemistry	27.5	29.1	35.7	22.6
Physics	66.7	55.9	58.7	45.7
Mathematical Science	34.1	19.1	28.8	16.9
Mathematics	31.9	16.2	26.8	15.0
Statistics	50.5	(44.9)	46.3	37.9
Computer Science	43.6	(34.9)	48.9	39.5
Enviromental Science	58.0	58.6	55.8	52.0
Earth Science	50.3	(53.3)	46.3	46.7
Oceanography	82.1	(63.6)	79.9	65.7
Atmospheric science	82.2	(94.1)	77.2	87.5
Other	70.2	(59.5)	77.5	36.8
Engineering	51.5	(50.4)	55.8	25.0
Life Science	60.1	58.7	62.3	54.3
Biological Science	59.0	58.8	57.0	52.6
Agricultural Science	67.5	(61.3)	76.7	72.6
Medical Science	55.4	57.7	66.6	61.3
Psychology	39.9	34.6	35.0	29.5
Social Science	29.8	21.5	24.6	18.3
Economics	30.8	(19.2)	23.6	13.3
Sociology/Anthropology	29.7	21.3	27.9	20.3
Other	29.2	22.7	23.5	17.8
Non-Science	27.6	26.2	27.3	23.0
Other			28.9	16.5

Parentheses indicate a very small sample size.

Source: NAS-NRC Roster of Doctoral Scientists and Engineers, 1973 (Unpublished Data).

Table 5.16

DOCTORAL SCIENTISTS AND ENGINEERS
SUPPORT BY GOVERNMENT FUNDS BY ACADEMIC RANK AND SEX

	Number Responding		% Distribution of Respondents		% Supported for Each Rank		% Distribution of Supported Persons	
Academic Rank	men	women	men	women	men	women	men	women
All Ranks	110,601	10,440			46.1	35.6		
Professor	44,090	2,129	39.9	20.4	46.7	27.0	40.3	15.5
Associate Professor	31,699	2,651	28.7	25.4	43.0	30.9	26.7	22.0
Assistant Professor	27,279	3,655	24.7	35.0	42.2	33.8	22.6	33.2
Instructor	1,049	386	0.9	3.7	48.8	21.5	1.0	2.2
Lecturer	623	304	0.6	2.9	40.0	27.6	0.5	2.3
Other	5,861	1,315	5.3	12.6	77.5	69.9	8.9	24.7

Source: NAS-NRC Roster of Doctoral Scientists and Engineers, 1973 (Unpublished Data)

Table 5.17

DISTRIBUTION OF ACADEMIC SCIENTISTS BY RANK, SEX AND FIELD
(SUMMARY OF SEVERAL INDEPENDENT STUDIES)

FIELD	YEAR		Total No.[a]	DISTRIBUTION BY RANK (Percentages add to 100 horizontally) Full Prof.	Assoc. Prof.	Assist. Prof.	Lesser Ranks	COMMENTS
Astronomy[1]	1972-73	men:	485	25%	16%	20%	39%	PhD astronomers at 28 graduate departments
		women:	44(9%)	11	14	11	63	
Physics[2]	1972-73	men:	2,985	30%	21%	34%	14%	At 743 four-year colleges with an undergraduate program only
		women:	188(6%)	30	18	30	23	
		men:	1,323	27	30	33	9	At 133 four-year colleges with an MA/MSc program
		women:	34(2.5%)	21	26	35	18	
		men:	5,135	43	26	26	5	At 158 universities
		women:	91(1.7%)	26	26	29	19	
		men:	560	59	16	19	6	At "top ten" universities[b]
		women:	5(0.9%)	40	20	20	20	
Mathematics[3]	1968-72[c]	men:	2,910	46%	16%	22%	16%	PhD mathematicians at 20 out of 35 top PhD granting universities
		women:	71(2.4%)	10	30	10	51	
Microbiology[4]	1970	men:	1,160	39%	28%	30%	3%	PhD microbiologists at all types of institutions
		women:	195(16.8%)	19	30	42	9	
Psychology[5]	1972	men:	2,160	39%	25%	30%	6%	Full-time faculty in graduate departments
		women:	366(14.5%)	20	24	31	25	
	1973	men:	2,043	39	26	29	6	
		women:	381(15.7%)	15	23	34	28	
Anthropology[6]	1971-72	men:	2,129	28%	24%	34%	14%	Data from the guide to departments of anthropology 1971-72
		women:	524(19.8%)	14	19	41	26	
	1973-74	men:	2,551	28	24	33	15	Data from the guide to departments of anthropology 1973-74
		women:	689(21.3%)	12	22	39	27	
Economics[7]	1972	men:	4,151	36%	25%	33%	6%	Full-time faculty, all departments
		women:	284(6.4%)	17	21	41	21	
		men:	1,121	50	19	29	2	Full-time faculty, 43 universities giving 2/3 of PhD's in economics
		women:	73(6.1%)	19	11	42	27	
	1974	men:	3,977	35	25	31	8	Full-time faculty, all departments
		women:	285(7%)	15	22	43	19	
		men:	1,164	50	20	28	2	Full-time faculty, 43 universities giving 2/3 of PhD's in economics
		women:	60(5%)	20	12	53	15	
Political Science[8]	1969	men:	4,030	30%	20%	32%	17%	Full-time faculty at 473[d] departments
		women:	371(8.4%)	14	16	33	38	
	1972	men:	4,672	30	25	35	10	Full-time faculty at 720[d] departments
		women:	456(8.9%)	13	22	39	26	
		men:	445	50	19	25	6	Full-time faculty at 18 leading[b] departments
		women:	23(4.9%)	13	35	30	22	
	1974	men:	5,072	33	26	29	11	Full-time faculty at 690[d] departments
		women:	561(10.0%)	15	20	43	22	
Sociology[9]	1970	men:	2,571	33%	24%	34%	10%	At all graduate departments
		women:	274(9.3%)	13	24	47	16	
	1971	men:	2,929	35	23	35	6	
		women:	320(9.8%)	13	26	44	17	
	1972	men:	2,658	37	23	35	5	
		women:	368(12.2%)	14	22	48	15	

[a] Women as percentage of total are given in parentheses.

[b] According to the rating system in Kenneth D. Roose, "A Rating of Graduate Programs", American Council of Education, Washington, D.C. 1970.

[c] Numbers and percentages for mathematicians represent year-persons, thus "four" can be one person for four years or four persons for one year.

[d] The original sources for these data (reference 8) do not explain why the number of faculty in 1972 at 473 departments is comparable to the number of faculty in 1971 and 1972 at a much larger number of departments.

[1] "Report to the Council of the AAS from the Working Group on the Status of Women in Astronomy,1973", AAS Bulletin 6 (3), Part2, 412, 1974.

[2] "Women in Physics", Bulletin of the American Physical Society, p. 740, June, 1972.

[3] Cathleen S. Morawetz, "Women in Mathematics", p. 131, Notices of the American Mathematical Society, April 1973

[4] Loretta Leive, "Status of Women Microbiologists", ASM News, 37 (3), 57, August 1971.

[5] "Survey of Departments of Psychology, 1972 & 1973", APA Committee on Women in Psychology, March 1974 (unpublished).

[6] 1971-72 and 1973-74 unpublished data from the Committee on the Status of Women in Anthropology; see also AAA Newsletter, 14 (2), 1973.

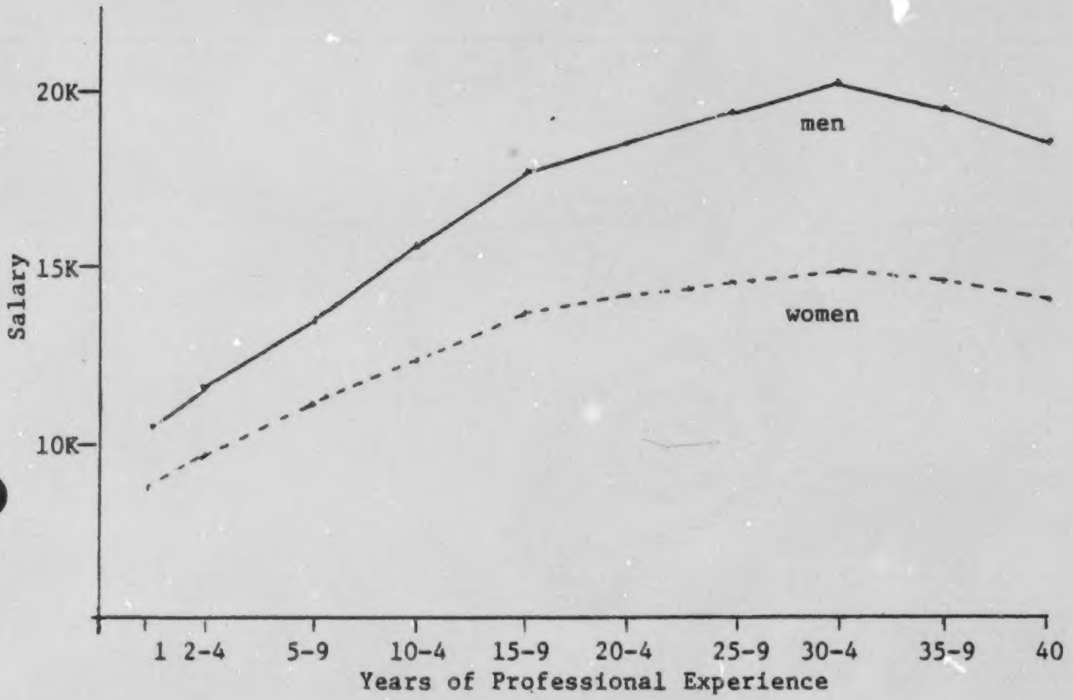
[7] Annual Report of the Committee on the Status of Women in the Economics Profession, 1972 and 1974, AEA (unpublished).

[8] "Women in Political Science", p. 53, APSA, Washington, D.C., 1971; 1972-73 and 1974-75 Surveys of Departments, American Political Science Association; Ada W. Finifter, "The Professional Status of Women Political Scientists: Some Current Data", PS, p. 406, Fall 1973.

[9] "The Status of Women in Sociology, 1968-72", The American Sociological Association, Washington, D.C., 1973.

Figure 5.1

MEDIAN ANNUAL SALARIES OF SCIENTISTS BY SEX AND YEARS OF PROFESSIONAL EXPERIENCE



Source: "American Science Manpower, 1970", NSF 71-45, National Science Foundation, Washington, D.C., 1970

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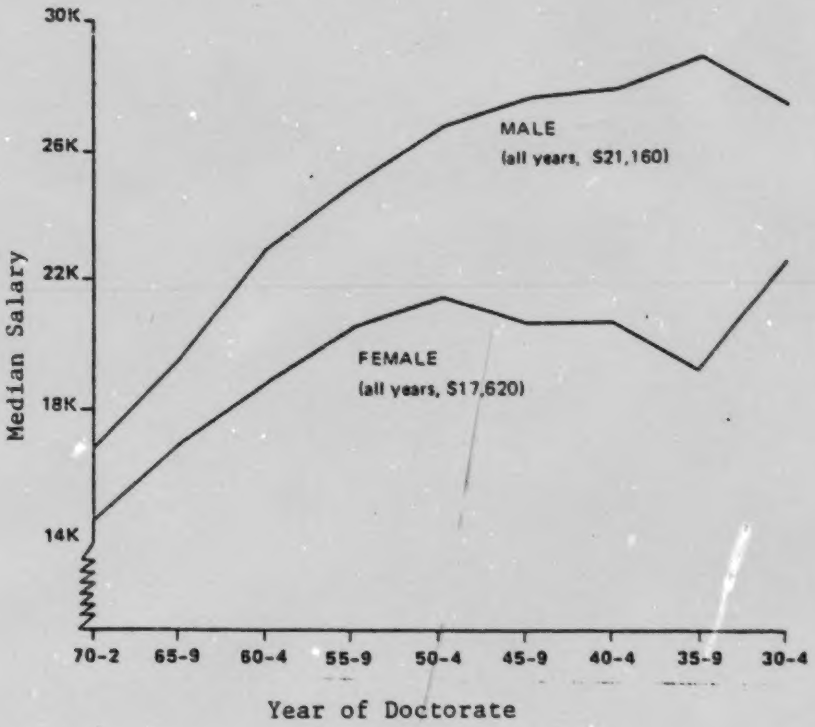
Figure 5.2

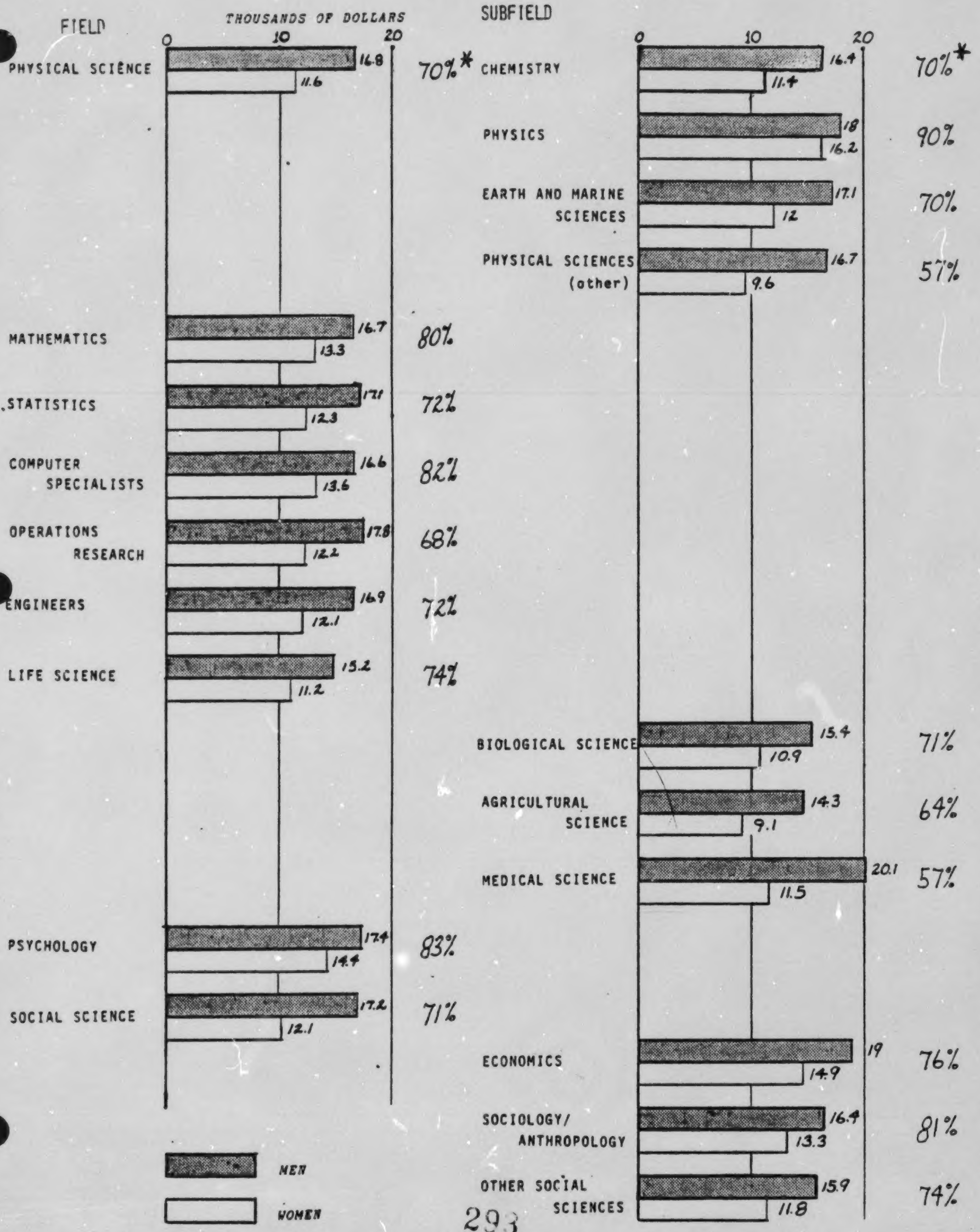
MEDIAN ANNUAL SALARIES OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX AND YEAR OF DOCTORATE



Source: NAS-NRC Roster of Doctoral Scientists and Engineers , 1973

Figure 5.3

MEDIAN SALARIES BY SEX AND FIELD



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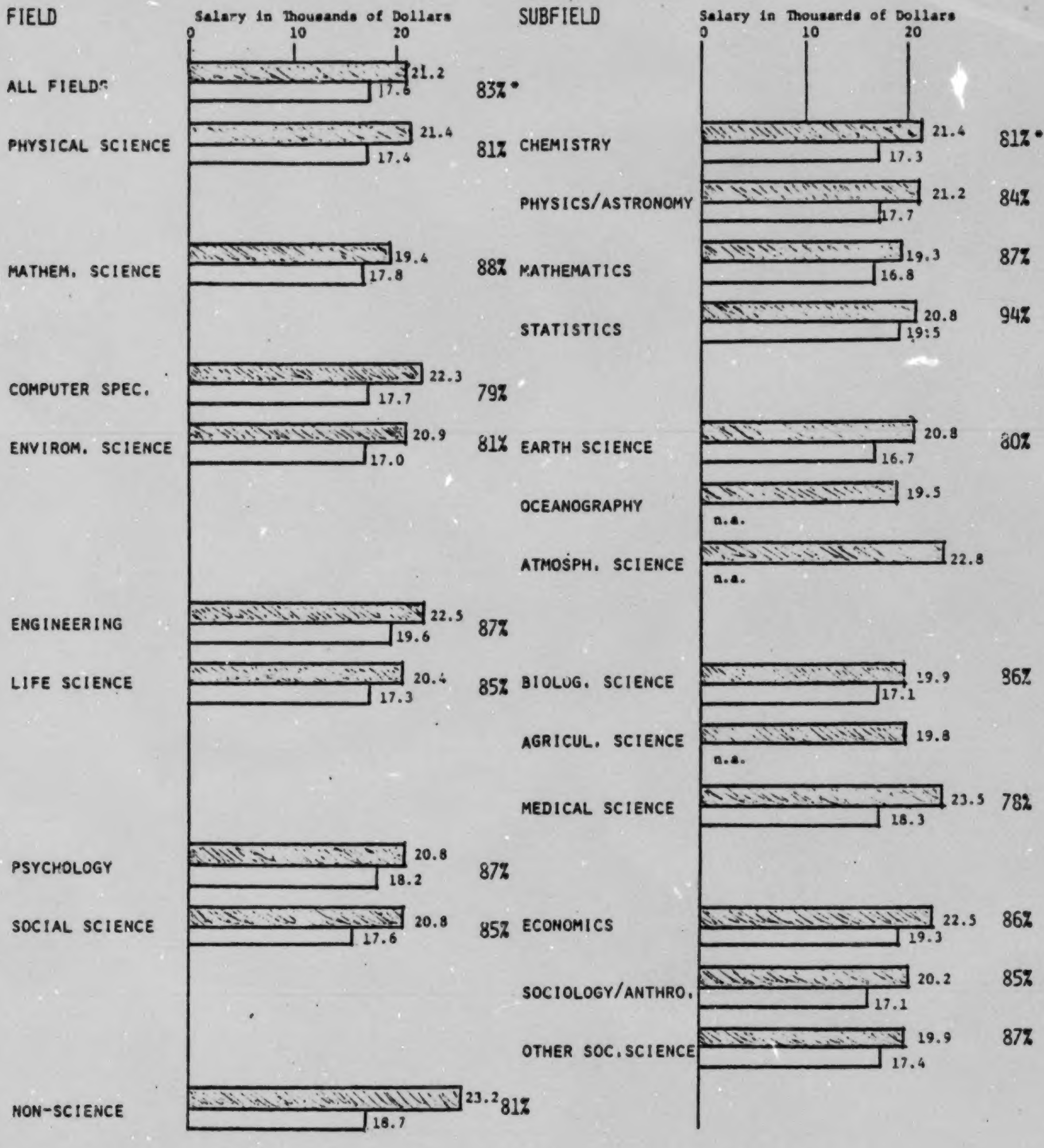
Source: 1972 Post-Censal Survey

* These percentages are female salaries expressed as a percentage of male salaries

Figure 5.4

MEDIAN SALARIES OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX, FIELD AND SUBFIELD



▨ men

☐ women

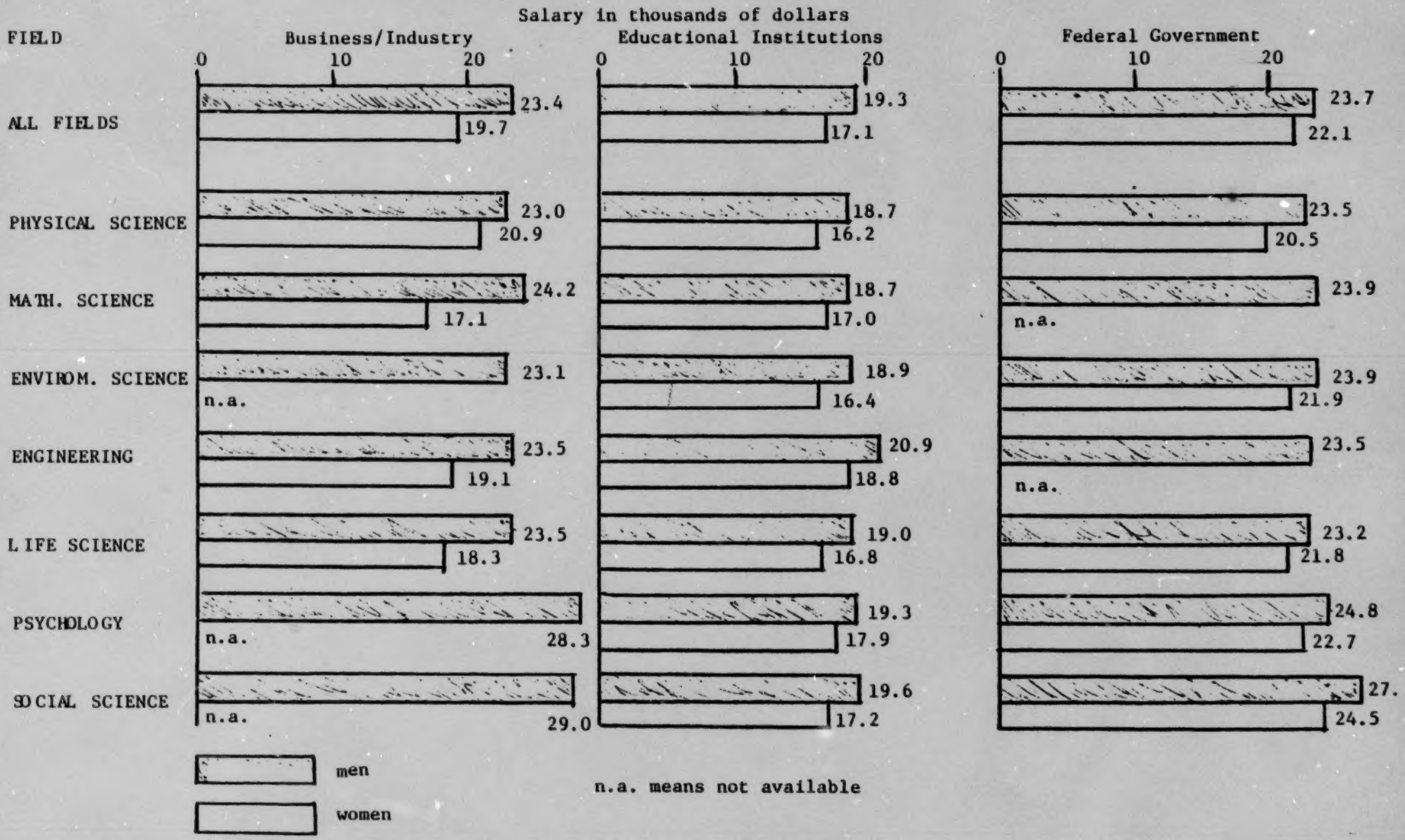
* These are female salaries as a percentage of male salaries.

n.a. means not available

Source: NAS-NRC Roster of Doctoral Scientists and Engineers, 1973

Figure 5.5

MEDIAN ANNUAL SALARIES OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX, FIELD AND TYPE OF EMPLOYER

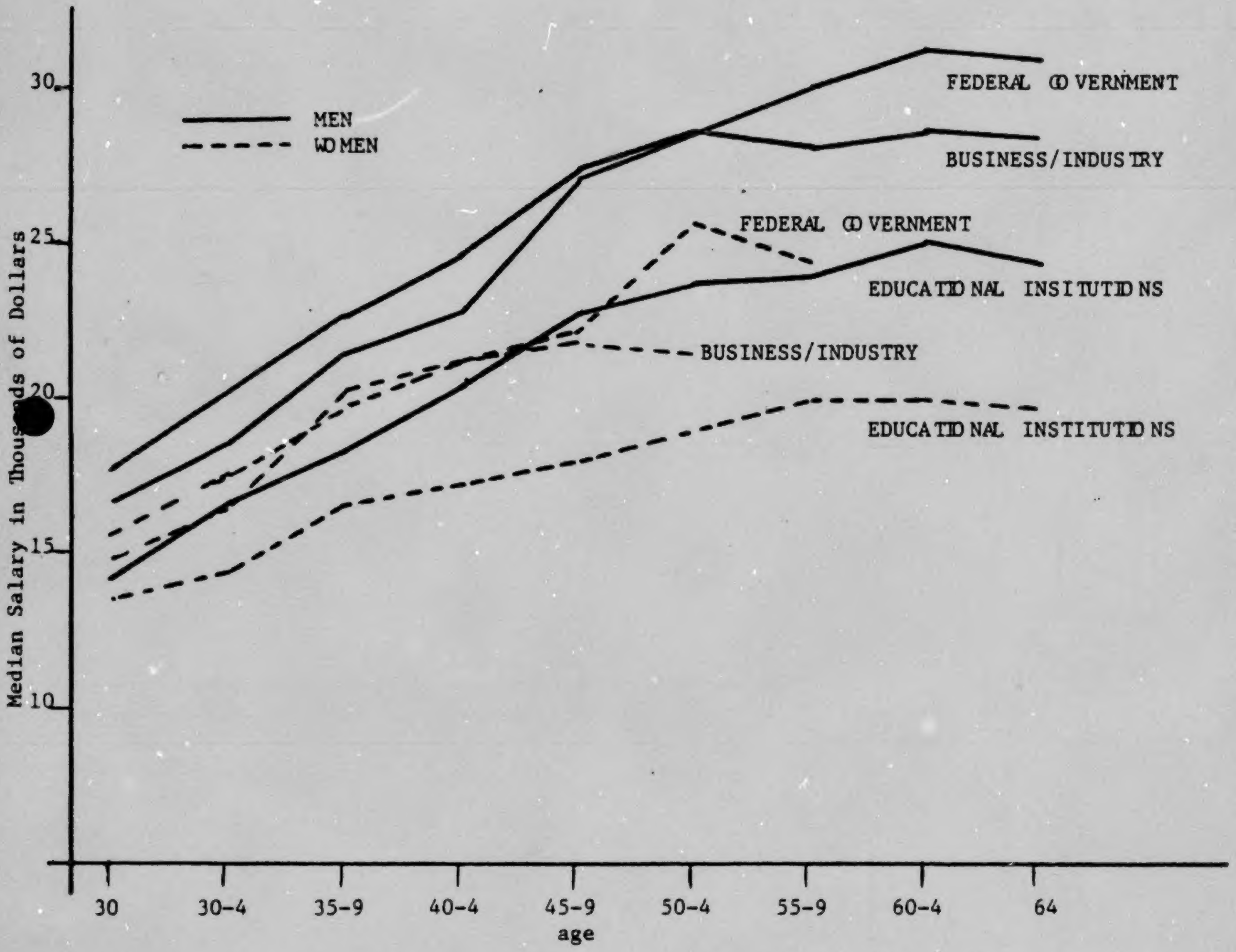


n.a. means not available

Source: NAS-NRC Roster of Doctoral Scientists and Engineers, 1973

Figure 5.6

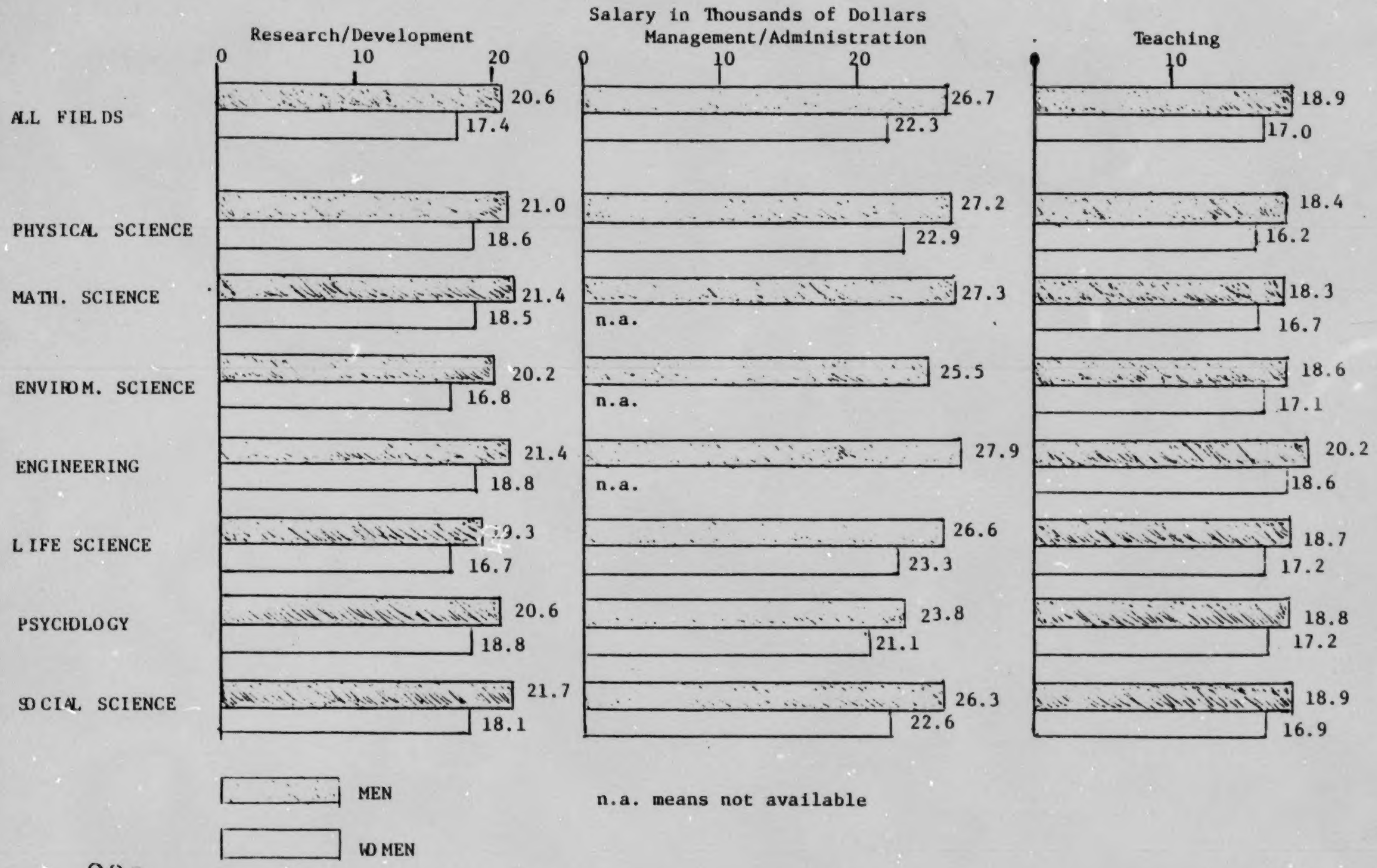
MEDIAN ANNUAL SALARIES OF DOCTORAL SCIENTISTS AND ENGINEERS
BY SEX, AGE AND TYPE OF EMPLOYER



Source: NAS-NRC Roster of Scientists and Engineers, 1973

Figur[illegible].7

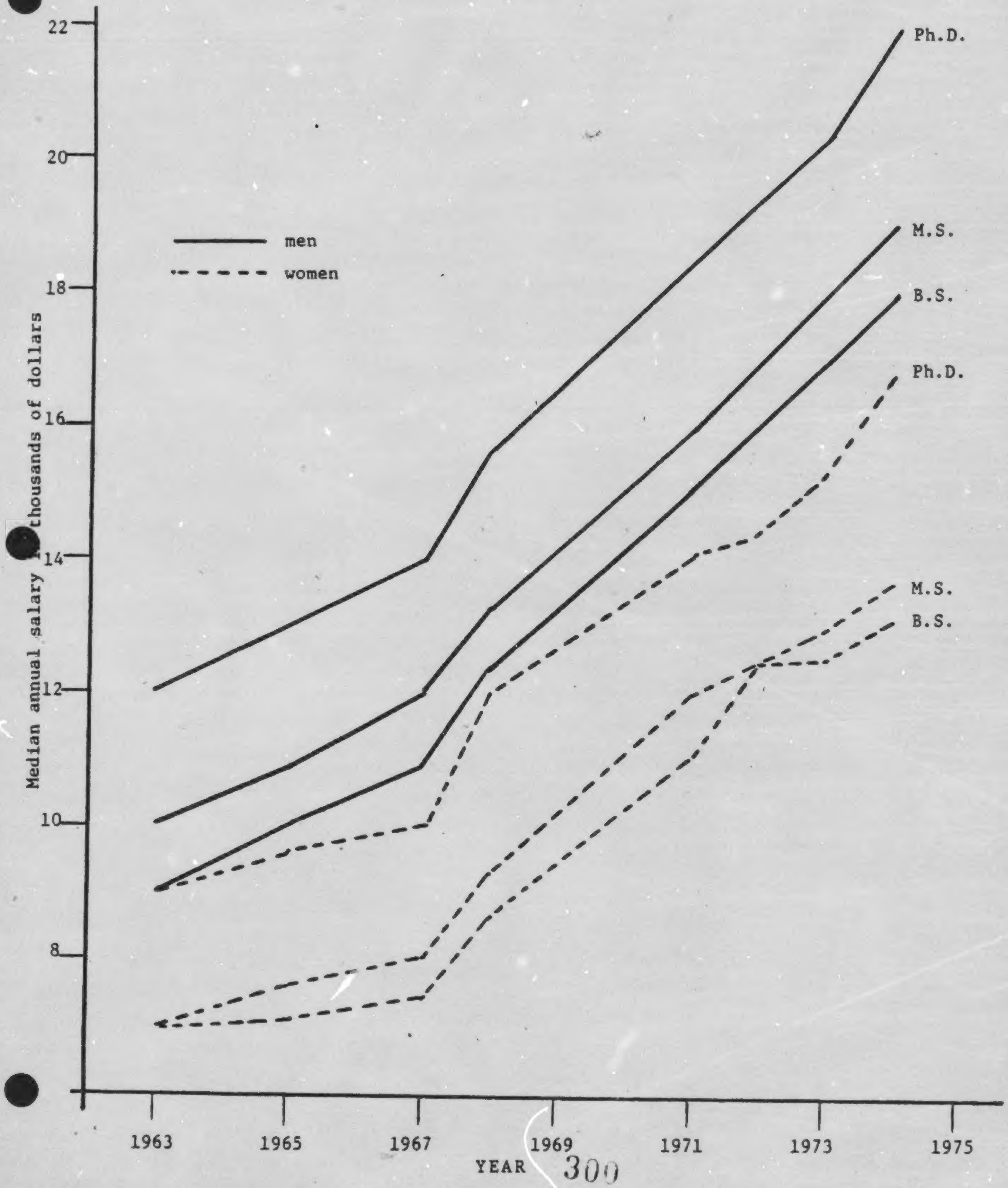
MEDIAN ANNUAL SALARIES OF DOCTORAL SCIENTISTS AND ENGINEERS BY SEX, FIELD AND TYPE OF WORK



Source: NAS-NRC Roster of Doctoral Scientists and Engineers, 1973

Figure 5.8

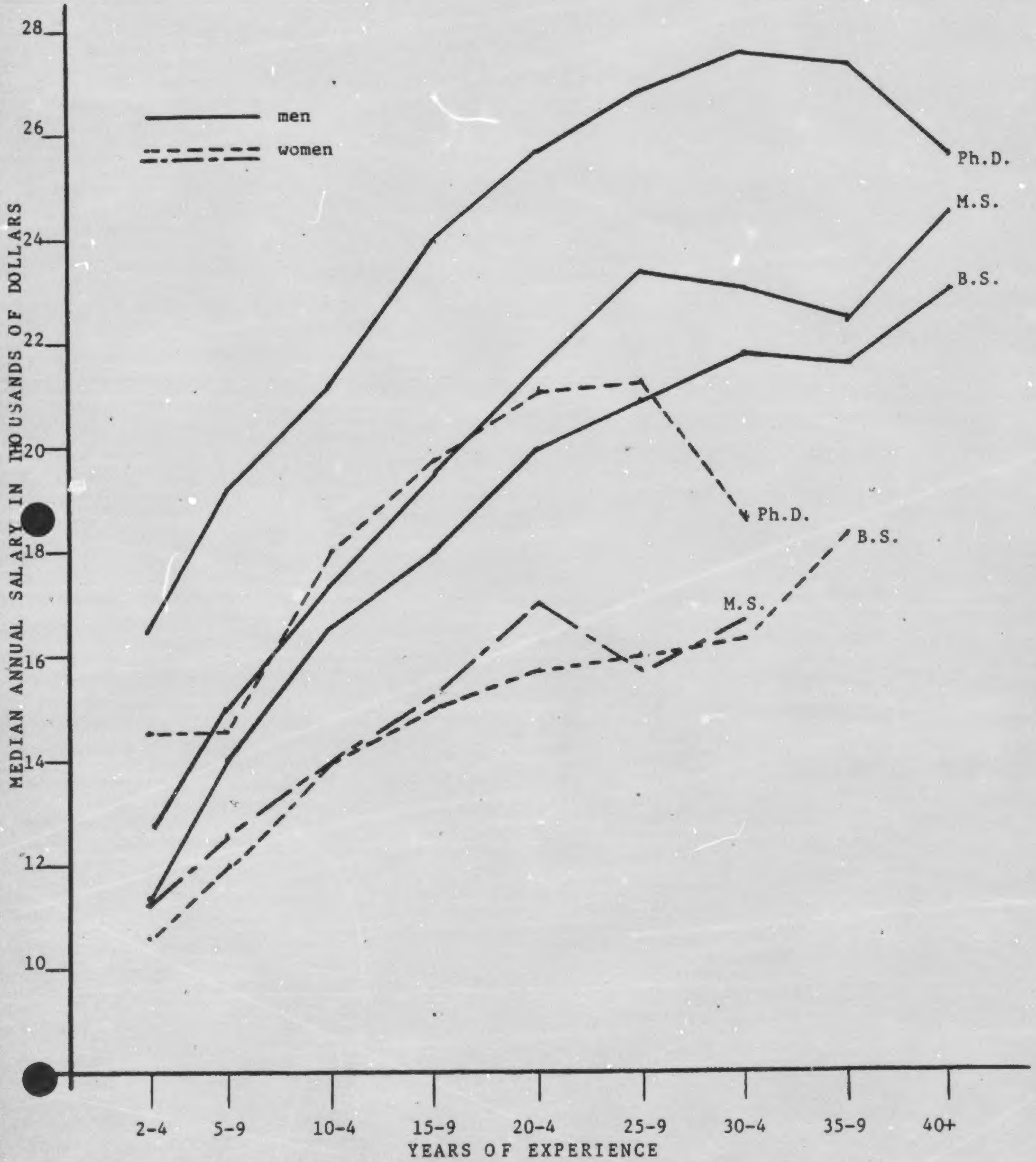
MEDIAN SALARY OF CHEMISTS BY SEX, YEAR AND DEGREE



Source: American Chemical Society Data presented by Sharon Johnson at the ACS's Annual Meeting in Chicago, August, 1973 (1974 data were added by the author)

Figure 5.9

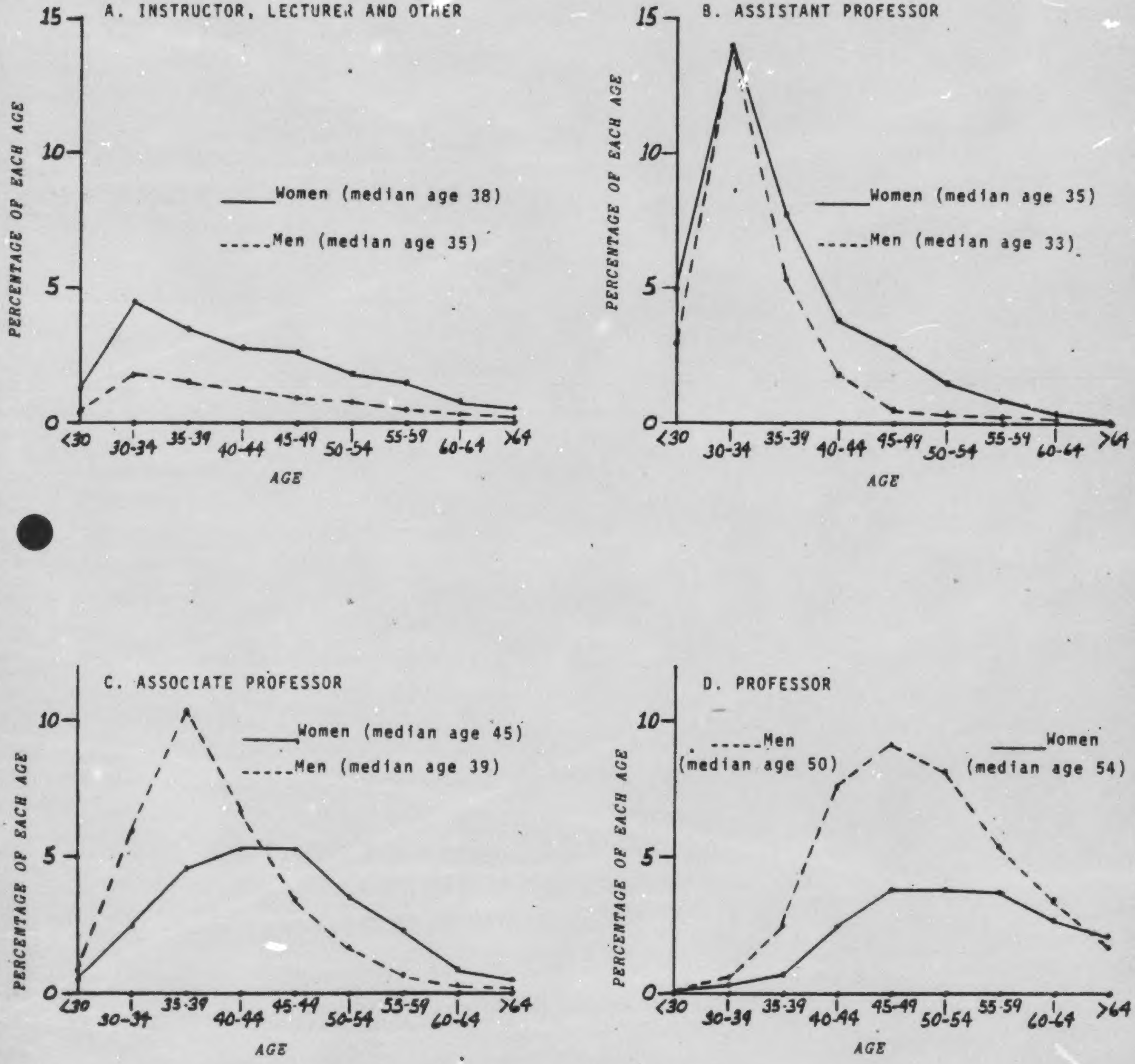
1974 CHEMISTS' MEDIAN SALARIES BY SEX, DEGREE AND EXPERIENCE



Source: 1974 Report of Chemists' Salaries and Employment Status, American Chemical Society, Washington, D.C.

Figure 5.10

AGE DISTRIBUTION OF DOCTORAL SCIENTISTS AND ENGINEERS IN EDUCATIONAL INSTITUTIONS BY RANK AND SEX



NOTE: The sum of the areas under each of the four curves are equal to 100% for each sex.

NAS-NRC Roster of Scientists and Engineers, 1973 (Unpublished Data).

SECTION 6

Summary and Conclusions

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Women constitute a small minority among scientists and engineers. Nevertheless women scientists exist in significant numbers. There are about seventy-three thousand women scientists and engineers, and their numbers are increasing rapidly.

Women scientists and engineers are less likely than men to receive advanced degrees. The more advanced the degree, the smaller the fraction of women among the degree recipients. Thus, over the past several decades, women received 22% of bachelor's degrees in science and only 9% of the doctorates. The discrepancy is particularly striking in mathematics; a third of the bachelor's degrees but only 7% of the doctorates are awarded to women.

Women are most likely to specialize in social sciences or psychology, life sciences are their next most frequent choice, fewer choose mathematical and physical science, and only very few go into engineering. The distribution of women scientists over the fields has not changed much since the twenties. Despite the recent marked increase in women doctorate recipients, the science professions continue to exhibit vocational sex segregation.

There is evidence indicating that women's scarcity in physical and mathematical sciences is not due to their lesser ability in these fields. On the contrary, it appears that for women doctorates there is a much greater preselection with respect to academic credentials and ability. Clearly, other factors besides ability influence the choice of specialty for women doctorates.

It has been observed that women take slightly longer than men to receive their doctorate. Two reasons for this are suggested by the data in this report. First of all, women are more likely to choose fields in which doctoral training is longer. Secondly, unlike most men, many women return to graduate school to obtain a doctorate in later years.

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The proportion of women scientists of all educational levels participating in the scientific labor force is about a third of that expected from the data for the total college educated population. This strongly indicates that a much larger proportion of women than men educated in science wind up working in non-science fields, most likely at sub-professional levels.

For doctoral scientists and engineers the difference in labor force participation is not so great. While there are slight variations by field, on the whole, 94% of men and 85% of women participate in the labor force.

When unemployment and underemployment data of scientists and engineers are compared, the differences between the sexes become much more striking. The unemployment rate of women doctoral scientists is 4% , four times larger than that of men. For women the highest unemployment rates occur in the youngest age group, reaching a maximum of 6% between the ages of 30 and 34, while for males the unemployment rates are almost independent of age. The highest unemployment rates for both men and women are in the physical sciences, 1.8% for both sexes and 7.3% for women.

Underemployment rates for doctoral scientists and engineers were established by examining employment in part-time positions, post-doctoral positions and non-science positions. For women the total underemployment rate was found to be 5.4% much larger than for men, 1.9%. The numbers cited above probably underestimate the unemployment and underemployment rates and should be regarded as the lower limit. They make it clear, however, that women fare much worse than men, and that the disparity is worst for younger women. The disparity in employment status between men and women is worse in natural sciences than in other fields. There is little to indicate that the employment status of women is showing any significant improvement.

Women scientists are much more likely to work in academic institutions and much less likely to work in government and industry compared to men. This pattern is particularly pronounced in physical and mathematical sciences. For doctoral scientists the pattern is similar; but the scarcity of women in business and industry becomes even more striking.

Women are much more likely to teach and much less likely to work as managers and administrators as compared to men. This holds for both doctoral and non-doctoral scientists. Again, the discrepancy is largest in the physical sciences.

The difference in status between men and women scientists becomes even more obvious when one looks at salaries. Women scientists earn consistently lower salaries than men, no matter where they work nor what they do. Thus, the median salary of a female doctoral scientist is 83% of that of her male collegue. For scientists with lesser degrees the salary gap is larger. The data indicate that the gap increases with years of experience. The salary gap is greatest in industry and smallest in federal government. The most recent data show very little improvement in the salary differential between men and women. There is some indication that the starting salaries in some fields are becoming comparable. On the other hand, the data on 1975 academic salaries show that the pay gap between men and women is widening.

The distribution of academic men and women by rank provides further insight into their relative status. All the data studied show that women are disproportionately concentrated in lower ranks. They also occupy a much higher percentage of marginal, non-ladder, temporary, or fringe positions. Moreover, women stay much longer in the lower ranks, their promotions are slower, and only a few make it to the top rank of professor. The salary data indicate that of the few who make it to the top rank even a smaller number attain salaries comparable to their male collegues.

It was found that academic women scientists are concentrated mostly in the least prestigeous schools. The most prestigeous universities have very few women scientists on their faculties.

On the whole, all the data in this work present a rather dismal picture of the status of women scientists and engineers. The only significant recent change is the marked increase in the proportion of women entering the scientific professions. Yet many highly trained and talented women are underpaid, underemployed and often unemployed. The most recent data show no improvement in this situation.

THE PARTICIPATION OF WOMEN
IN
SCIENCE AND ENGINEERING

A Psycho-Social Perspective

Denise Horton

SECTION 1

Education and
Employment Trends

When one evaluatés educational opportunites vis-a-vis employment opportunities for women (i.e., the "supply" versus the "demand" side of the equation) a central theme appears to emerge. This theme may have important consequences for long-term planning and may also hark back to the lack of impact on the world of work of the increasing number of women who received college educations in the '50s and '60s and did not greatly impact the labor force at that time.

The theme which runs through the myriad of rapid changes in the educational picture for women during the 1960s and 1970s, and, based on available data, for projections through the 1980s, seems to be "the more things change, the more they stay the same."

Women are making significant advances in some scientific fields, simply maintaining an unsatisfactory status quo in others, and steadily losing ground in still others. No clear picture, certainly, of growing equality emerges. One does not, in fact, observe even a modest but steady progress. Compared with the dramatic educational boom of the 1960s, projections for the '70s and '80s strike the somber note of "business as usual" -- with perhaps a few more women having been brought into the business. The wide-ranging social change which is popularly claimed be feminists and educators alike is not overtly discernible at this level of human endeavor.

In view of recent economic educational and employment trends in the United States, three simplistic possibilities could be considered. The female professional may: a) choose or acquiesce in relative underemployment; b) significant numbers of women currently enrolled in higher education institutions will not complete their professional training; or c) there will arise an unprecedented disparity between professional expertise and the opportunity to exercise it for a growing number of women in the sciences. It should be pointed out that the last mentioned possibility may occur without respect to sex and has been sufficiently observed to warrant popular notice and potential comment.[1]

Hazarding likely developments in this arena in the future from time-limited growth curves is an activity encompassing more and varied sources of error than either the projection of economic trends or weather forecasting from similarly limited bases. The validity of the mildly prophetic comments derived in this section are reflective of two major considerations. (1) The small and selective number of interrelated surveys quoted were chosen from all those available on the basis of experience gained sifting material more extensively treated in other sections of this report.[2] (2) The points delineated are in accord with subjective impressions and anecdotal material furnished by concerned feminists actively engaged in and demonstrating achievement in the scientific professions. With these caveats, the following partial analysis has been made.

The magnitude of the potential problem posed by the possibility, mentioned earlier, that women and men may possess the necessary expertise to perform in these fields and will not have the chance to do so can be adduced from the following relevant data. By 1982, there will be approximately 506,000 women enrolled for advanced degrees in the United States, while 178,500 women will have earned advanced degrees.[3] These figures represent a 36% increase in enrollment and a 56% increase in earned degrees over 1972 figures.[4] This means that by 1985, according to a second source, women will comprise 27.6% of all enrollees for advanced degrees[5], and 25.9% of the Ph.D.'s awarded will be held by women.[6]

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[1] Time, March 21, 1976

[2] Table 1 . Frankel, Martin M., and Beamer, J. Fred, Projections of Educational Statistics to 1982-83, 1973 Edition, National Center for Educational Statistics, Office of Education, U.S. Department of Health, Education and Welfare, Pub. No. (OE) 74-11105, Washington, D.C., U.S. Government Office, 1974.

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This pattern of truly equal growth demonstrates quite clearly the continuing progress made by women into the formerly male bastion of professional training. However, it does not begin to compare with the explosion of women into advanced degree programs during the 1960s, during which, one for example, saw a 200% increase in enrollment figures for women between 1962-72 and 241% increase in the number of earned degrees at all levels.[7] Whether the less dramatic progress of the '70s and '80s signals the beginning of a discouraging trend back to "business as usual," or is simply a natural leveling-off following a period of intense activism and ample funding, remains to be seen.

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[3] Table 6 . Projections of Science and Engineering Doctorate Supply and Utilization, 1980 and 1985, National Science Foundation, Division of Science Resource Studies, Washington, D.C., National Science Foundation, NSF 75-301, 1975.

[4] Exact comparisons cannot be made since enrollment figures are available only as cumulative totals of enrollees for all advanced degrees while earned degree data used is for Ph.D.'s only.

[5] Table 6 . NSF, Projections of Science and Engineering Doctorate Supply and Utilization.

[6] Table 5 . NSF. Projections of Science and Engineering Doctorate Supply and Utilization.

[7] Table 1 . Frankel and Beamer, Projections of Educational Statistics.

How do these educational trends compare with those projected for males? According to one source, between 1970 and 1985, there will be an overall drop in the number of both male enrollees for, and recipients of, advanced degrees in science and engineering.[8] Looking at the "earned degrees" data, we see that, although relatively small in size -- some 3,300 fewer doctorates over the 15 year period -- this drop in figures may be considered significant in that it represents the first time in recent history that doctorate supply in scientific fields will be characterized by a steadily increasing number of women accompanied by an equally steady decrease in the number of men. Similar downward trends are projected for male enrollment figures as cited earlier. Approximately 43,000 fewer males will apply for advanced degrees in science between 1970 and 1985, while some 7,300 more women will do so.[9]

Factors that may be instrumental in accounting for this projected drop in male enrollment and earned degrees are: meeting affirmative action requirements will force many institutions of higher education to allocate graduate training slots which were formerly reserved for males; a disenchantment with technology and science, coupled with increasingly widespread predictions of a Ph.D. "surplus" in those fields and a depressed economic climate, will act as deterrents to career-oriented young men. Young women, on the other hand, may be less cognizant of these potential limitations, or if in fact aware, may be more determined as relative newcomers to the academic/professional game, to persist despite possible future difficulties.

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[8] Table 9 . . Projections of Degrees in Science and Engineering Fields to 1985, National Science Foundation, Division of Science Resource Studies, NSF 76-301, Washington, D.C. In preparation* N.B. In the process of revision, some of the projected numbers have been changed. At this point, it would appear that the numbers used in this project are conservative. * Cited by permission.

[9] Table 9 . Projections of Degrees in Science and Engineering Fields, NSF.

According to a second source, projections for 1972-82 will show a leveling off across the board for both sexes, probably due to lowered job market prospects, particularly in academe which employs the majority of doctorates, and to increasing unavailability of funds for graduate training.[10] The leveling off trend is most marked for male enrollment figures, where an increase of only 3.1% is projected over the 1972-82 period.[11] This differs from the first source cited where an actual decrease in these figures is projected. Thus this second source anticipates that despite a projected leveling off, the number of Ph.D.'s earned and enrollees for these degrees will continue to rise for both sexes -- although slowly -- for the forseeable future.

The following conclusions can be drawn based on the described trends, and are illustrated in Figure I:

- Parallel rates of increase in enrollment for both sexes seen in the '60s will give way to a sharp leveling off for men in the '70s and early '80s. There is disagreement on just how sharp this leveling off will be -- the number of male enrollees may, in fact, decrease for the first time in recent history. Should this occur, then the projected increase in the percentage of women enrollees between 1975 and 1985 will in part be accounted for by a drop in the number of male enrollees, rather than,as one might hope, by a significant increase in the number of female enrollees. Thus, the larger portion of the educational pie which women will appear to have gained by 1985 may be a more statistical reflection of a considerably smaller pie than it is of a significant breakthrough for women.

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[10] Table 1 . Frankel and Beamer, Projections of Educational Statistics.

[11] Table 1 . Frankel and Beamer, Projections of Educational Statistics.

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- Closely parallelled rates of increase in number of degrees earned will probably be seen for both men and women, with women having a slight edge. How slight an edge is perhaps best brought out by the observation that, based on current trends, it will still be well into the 21st century before women achieve equal representation with men as recipients of advanced degrees.
- The rate at which women acquire advanced degrees will increase slightly over the '70s (although the numbers will not) compared with the rate for men, while in the 1960s the opposite trend was observed. (See Figure 1.) Thus, while women will still be dropping out of graduate training, the rate at which they do so will be slowing down. In other words, women will be catching up with men, although very slowly.

Having looked briefly at the overall picture of higher education in the 1960s and 1970s, let us now examine the specific trends characteristic of women in science and engineering programs. In all science/engineering fields except computer science, a greater percentage of all Ph.D.'s will be earned by women during the 1970s than were earned by women in the 1960s.[12] During the 1960s, women earned 8.4% of all science and engineering doctorates granted in the United States.[13] Projections for the '70s indicate that women will earn 14.1% of these Ph.D.'s, an increase of 6 percentage points over the previous decade.[14] In certain fields, however, progress in this direction is much slower. In engineering, for example, where one finds the greatest projected increase in the proportion of women Ph.D.'s -- some 1100% -- between 1970 and 1985, the rate of increase reduces to only one-half of one percentage point per year.[15] In the physical sciences, although 14.6% of the 1985 Ph.D. recipients will be women compared with 5.5% in 1970, the rate of increase averages out to only 0.6 percentage points yearly.[16] In social sciences, an area in which women historically have received more acceptance and have prospered more rapidly as a result, the data are not much better. A 129% increase in the proportion of Ph.D.'s earned by women from 1970 to 1985, while numerically impressive, reduces to an average gain of only 1.4 percentage points per year.[17]

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[12] Table 2 , Table 15. NSF, Projections of Degrees in Science and Engineering Fields.

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[13] Table 2 . "Proportion of Doctorates Earned by Women, by Area and Field, 1960-69," WEAL Report, Washington, D.C., 1971. Prepared by the Council for University Women's Progress, University of Minnesota from data at the U.S. Dept. of Health, Education and Welfare, Earned Degrees Conferred: Bachelor's and Higher Degrees.

[14] Table 7 . NSF, Projections of Degrees in Science and Engineering Fields; WEAL Report.

[15] Table 5 . NSF, Projections of Degrees in Science and Engineering Fields.

[16] Table 5 . NSF, Projections of Degrees in Science and Engineering Fields.

[17] Table 5 . NSF, Projections of Degrees in Science and Engineering Fields.

At these rates, it is clear that it will take women well into the 21st century to achieve equal representation with men in scientific fields, with an even longer delay operative in particularly misogynic or occupationally segregated sub-fields.

The relative popularity of the respective science/engineering disciplines for women aspiring to the doctorate is projected to remain much the same during the 1970s as during the 1960s, with psychology and the social sciences leading the list of choices, and engineering and computer science falling at the lower end of the scale.[18] Despite the much-touted effects of the current feminist movement and increased recruitment efforts in underrepresented fields, a comparison of the relative popularity of the various scientific fiels (as inferred from the percentage of women choosing to earn their doctorates in each) indicates that the proportional representation by field will remain about the same: "soft" sciences are at the top, "hard" sciences, such engineering, at the bottom.[19]

1960s	% Women Ph.D.s	1970s (projected)	% Women Ph.D.s
Psychology/Social Science	31.3%	Psychology/Social Science	23.7
Biological Science	13.8	Biological Science	17.4
Mathematical Science	6.5	Mathematical Science	11.1
Physical Science	4.6	Physical Science	7.7
Computer Science	2.5	Engineering	2.2
Engineering	0.4	Computer	1.5

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[18] Table 2 . WEAL Report; Table 3 . Kistiakowsky, Vera, "On the Availability of Women Qualified for Positions at Universities and Colleges," Testimony submitted to the Subcommittee on Education, U.S. House of Representatives, October 11, 1974.

[19] Table 2 . WEAL Report; Table 3 . Kistiakowsky, "Availability of Women Qualified."

It appears from various data surveyed that women will probably achieve equal representation with men in the social sciences well before any other scientific fields. In 1985, over one-third of the social science Ph.D.'s granted will be to women, and almost one-half of the enrollees will be women.[20] As stated earlier, more Ph.D.'s will be earned in this field by women than in any other sciencific field -- in fact, nearly half of all science/engineering Ph.D.'s granted to women over the 1970s will be in social science and psychology.[21] Almost four times as many women will earn social science Ph.D.'s in 1985 as did in 1970, a growth rate exceeded only by that of engineering.[22]

These growth trends, although a generally positive sign, provide a disturbing contrast with NSF science/engineering doctorate labor force projections for the 1970s and early 1980s. According to these projections, the greatest discrepancy between doctorate supply and utilization is projected to occur in the social sciences[23] (Figure 2) -- precisely the area in which, as illustrated above, the greatest proportion of women will continue to earn their Ph.D.'s. Since labor force projections indicate that only 63% of all Ph.D. social scientists will be employed in science/engineering related jobs by 1985, obviously some 37% will be forced to look outside the field for employment.[24] Coincidentally, women are projected to comprise almost 37% of the social science Ph.D. population by 1985.[25] We do not mean to suggest by this facile juxtaposition of figures that all 37% of the non-science job slots are destined for the 37% of social scientists who happen to be women. The point is simply that women in relatively large numbers appear to be training for employment in a field where job opportunities are, in fact, projected to shrink dramatically over the next decade. In view of the discrimination that women have traditionally faced and continue to face in an increasingly competitive job market, it seems reasonable to conclude that a significant, and perhaps disproportionate number of women will therefore be represented among the "displaced" 37%. While training for deadend careers, or careers where work is unavailable or difficult to find, is by no means a new experience for women at the Ph.D. level. Such a miscalculation implies an even greater, and more senseless, waste of both talent and funds, and necessary measures should be taken to avoid it.

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[20] Table 5 and Table 6 . NSF, Projections of Degrees in Science and Engineering Fields.

[21] Table 7. NSF, Projections of Degrees in Science and Engineering Fields.

[22] Table 4. NSF, Projections of Degrees in Science and Engineering Fields.

[23] Table 8 . NSF, Projections of Science and Engineering Doctorate Supply and Utilization.

While the smallest proportion of science/engineering doctorates earned by women in the '60s was in engineering,[26] in the '70s the smallest proportion of women doctorates will be found in computer science.[27] This is the only field where the percentage of women Ph.D.'s is expected to drop during the '70s, although the numbers will increase sharply. This is probably due to the rapid expansion of the field mostly associated with an influx of male Ph.D.'s.[28] So we find that while women received 2.3% of the Ph.D.'s awarded in the '60s, they will make up only 1.5% of the same group in the '70s.[29] Large numbers of women will, however, be receiving Masters degrees, a phenomenon which will be looked at further later.

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[24] Table 8 . NSF, Projections of Science and Engineering Doctorate Supply and Utilization.

[25] Table 5 . NSF, Projections of Degrees in Science and Engineering Fields.

[26] Table 2 . WEAL Report.

[27] Table 3 . Figures apply for years 1972-81 only. Table . Kistiakowsky, "Availability of Women Qualified."

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Since there is currently considerable controversy surrounding projections for women in engineering, the following observations can be made with only a limited degree of confidence. However, according to one source, the greatest percentage increase in both enrollment figures (+200%) and Ph.D.'s earned (+1100%) during the '70s will occur in engineering.[30] Even with these dramatic projected increases, however, we still find that women will comprise only 2.2% of all engineering doctorates granted during the '70s, the lowest proportion of any field except computer science.[31] In other words, of the more than 10,000 degrees to be granted, only some 200 will go to women.[32] Other sources, as mentioned earlier, have projected an actual drop in the number of women engineers, while still others foresee a mixed picture depending upon which engineering subfield one chooses to examine. Since a detailed examination of the future of women in engineering is beyond the scope of this report, we are unable at this point in time to reach any clearcut conclusions regarding the future of women in this important area.

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[28] Table 3 . Kistiakowsky, "Availability of Women Qualified."

[28] Table 3 . Kistiakowsky, "Availability of Women Qualified."

[29] Table 3 . Kistiakowsky, "Availability of Women Qualifed."

[30] Table 5 and Table 6 . NSF, Projections of Degrees in Science and Engineering Fields.

[31] Table 7 . NSF, Projections of Degrees in Science and Engineering Fields.

[32] Table 7 . NSF, Projections of Degrees in Science and Engineering Fields.

From the selected sources cited above, the slowest growth rate for the 1970s, in terms of the number of women entering a given field, is projected to occur in the life sciences and the mathematical sciences. Between 1970 and 1985, only a 111% increase is projected, compared with, for example, a nearly 400% porjected increase in the social sciences and 1100% increase in engineering. This slow growth rate is significant when one considers again the general question of employment prospects for women in science. Projections for employment in the life sciences are excellent. Fully 93% of the Ph.D. population is expected to be employed in science/engineering in 1985, compared with the 63%, for example, cited earlier for social scientists. Yet, the number of women Ph.D.'s in this field is expected to increase at a slower rate than almost any other scientific field. Thus although the life sciences are the second preferred field for women, from the foregoing, it can be seen that women will not be entering these fields at a rate consonant with the opportunities potentially available within them. Thus, it would seem reasonable to infer that, as in social sciences, simple factors such as supply and demand are not the key ones influencing women in their choice of careers.

Table 1. Enrollment/ Degrees Received for Advanced Degrees, All Fields, 1961-1982

	Men		Women	
	Enrollment (in thousands)	Degree	Enrollment (in thousands)	Degree
1961-1962		95773		30720
1962-1963	298	101906	124	33483
1963	327	110109	137	37599
1964	373	119984	167	42390
1965	423	138841	196	50743
1966	458	152433	224	58363
1967	498	166939	255	67686
1968	514	178782	283	77180
1969	529	185454	299	68427
1970	569	201220	331	99342
1971	567	211400	341	104600
1972	572	221700	372	114300
1973-1974	573	231700	390	123500
1974	575	236800	411	132100
1975	582	243200	430	140000
1976	592	259700	447	147200
1977	601	255200	465	154400
1978	606	261000	480	161000
1979	607	265700	491	166700

Figures in degrees column are sum total numbers of first professional degrees, master's degrees and doctor's degrees.

Source: Martin M. Frankel & J. Fred Beamer. *Projections of Educational Statistics to 1982-83, 1973 Edition.* National Center for Educational Statistics, Office of Education.

Table 2. Proportion of Sciences and Engineering Ph.D's Earned by Women, by Field, 1960-1969

	Social Sciences	Physical Sciences	Mathematical Sciences	Computational Sciences (1964-1969 only)	Biological Sciences	Engineering	Psychology
Total number of Doctorates Earned 1960-1969	18662	25736	6166	158	17708	18572	9135
Total number of Doctorates Earned by Women 1960-69	2072	1179	401	4	2448	82	1845
Percentage of Doctorates Earned by Women 1960-69	11.11	4.6	6.51	2.51	13.81	0.41	20.21

	Total Sciences and Engineering Fields
Total number of Doctorates Earned 1960-1969	96137
Total number of Doctorates Earned by Women 1960-1969	8031
Percentage of Doctorates Earned by Women 1960-1969	8.4

Source: WEAL Report. "Proportion of Doctorates Earned by Women, by Area and Field, 1960-1969." Washington, D.C.: Women's Equity Action League, 1971. Higher Education General Information Survey. *Earned Degrees Conferred, Higher Degrees: 1960-1969.* Office of Education, National Center for Educational Statistics.

Table 3. Projections of the Number and Percent of Ph.D's Awarded in Computational Sciences and Engineering

Computational Sciences	Number of men	Number of Women	Percent of Women
Ph.D's			
1962-71	389	9	2.3
1972-81	2690	40	1.5

Engineering	Number of men	Number of Women	Percent of Women
Ph.D's			
1962-71	24,903	123	0.5
1972-81	42,700	530	1.2

Source: Vera Kistiakowsky. "On the Availability of Women Qualified for Positions at Universities and Colleges." Testimony submitted to the Subcommittee on Education, U.S. House of Representatives. October 11, 1974.

Table 4. Female Enrollment for Advanced Degrees/ Earned Ph.D's, by Field, Selected Years 1970-85

PROBABLE MODEL

Year	Social Science	Physical Science	Mathematical Science	Life Science	Engineering	Total
1.						
1984-1985	2600	300	100	1250	200	4450
1980	2000	300	150	1050	150	3650
1975	1300	300	150	800	50	2600
1970	670	236	98	499	24	1527
2.						
1984-1985	28950	5350	7800	15350	2500	59950
1980	29500	5550	7500	14350	2150	59050
1975	26300	5300	6600	12800	1600	52600
1970	20231	4672	6640	10862	1107	43512

1. Ph.D. Degrees Earned
2. Enrollment for Advanced Degrees

N.B. In the process of revision some of the projected numbers have been changed. At this point it would appear that the numbers used in this projection are conservative.

Source: National Science Foundation, Division of Science Resource Studies. Projections of Degrees in Science and Engineering Fields to 1985. Washington, D.C.: National Science Foundation, NSF-76-301. In preparation. Cited by permission.

Probable Model

Year	Social Science	Physical Science	Mathematical Science	Life Science	Engineering	Total
1984-1985..	36.9	14.6	15.4	25.5	8.0	25.9
1980....	29.2	10.3	15.0	21.4	4.8	19.4
1975....	22.6	8.1	12.0	17.8	1.4	13.9
1970....	16.1	5.5	7.3	12.1	0.7	8.7

N.B. In the process of revision some of the projected numbers have been changed. At this point it would appear that the numbers used in this project are conservative.

Source: National Science Foundation, Division of Science Resource Studies. Projections of Degrees in Science and Engineering Fields to 1985 Washington, D.C.: National Science Foundation, N.S.F. 76-301. In preparation. cited by permission.

Table 6. Proportion of Women Enrolling of Advanced Degrees, by Field, Selected Years 1970-1985

Probable Model

Year	Social Science	Physical Science	Mathematical Science	Life Science	Engineering	Total
1984-1985	43.7	19.7	24.2	28.6	6.6	27.6
1980......	37.9	16.6	23.4	26.2	5.1	24.5
1975.....	33.7	14.1	21.5	23.9	3.0	20.8

N.B. In the process of revision some of the projected numbers have been changed. At this point it would appear that the numbers used in this project are conservative.

Source: National Science Foundation, Division of Science Resource Studies. Projections of Degrees in Science and Engineering Fields to 1985. Washington, D.C.: National Science Foundation, NSF. 76-301. In preparation. Cited by permission.

Table 7. Comulative Number and Pecent of P.h.D's Earned by Men and Women, by Field, 1970-1980

	Social Sciences	Physical Science	Mathematical Sciences	Life Sciences	Engineering	Computational Science	Total
Number of both sexes.	16771	10913	3593	13531	10281	2730	57219
Number of women..	3970	836	398	2349	224	40	7817
Percent of women ...	23.7	7.7	11.1	17.4	2.2	1.5	

N.B. In the process of revision some of the projected numbers have been changed. At this point it would appear that the numbers used in this project, are conservative.

Source: National Science Foundation, Division of Science Resource Studies, Projections of Degrees in Science and Engineering Fields to 1985. Washington, D.C.: National Science Foundation, N.S.F. 76-301. In preparation. Cited by Permission.

Table 8. [illegible]ummary of Science and Engineering Doctorate [illegible]abor Force and Utilization, by Field of Degre[illegible]1972 and 1985

Item	Social Science	Physical Science	Mathematics	Life Science	Engineering	Total
1972						
Labor Force....	53	65	13	57	34	221
Science & Engineering utilization...	47	61	2	54	32	206
Non-Science utilization.......	6	5	1	3	2	15
Science & Engineering as percent of Labor Force...	89	93	96	95	95	93
1985						
Labor Force...	113	85	22	92	65	375
Science & Engineering utilization...	71	76	16	85	45	293
Non Science utilization.......	42	9	6	7	18	82
Science & Engineering as percent of Labor Force...	63	89	73	92	71	78

Source: National Science Foundation, Division of Science Resource Studies, Projections of Science and Engineering Doctorate Supply and Utilization, 1980 & 1985. Washington, D.C.: National Science Foundation, NSF. 75-301, 1975.

Table 9. Enrollment for Advanced Degrees in all Science and Engineering Fields - 1975 & 1985

year	number
1984-85	157,100
1974-75	200,350

Science and Engineering Ph.D's Earned by Males - 1975 & 1985

year	number
1984-85	12,700
1974-75	16,050

N.B. In the process of revision some of the projected numbers have been changed. At this point it would appear that the numbers used in this proj

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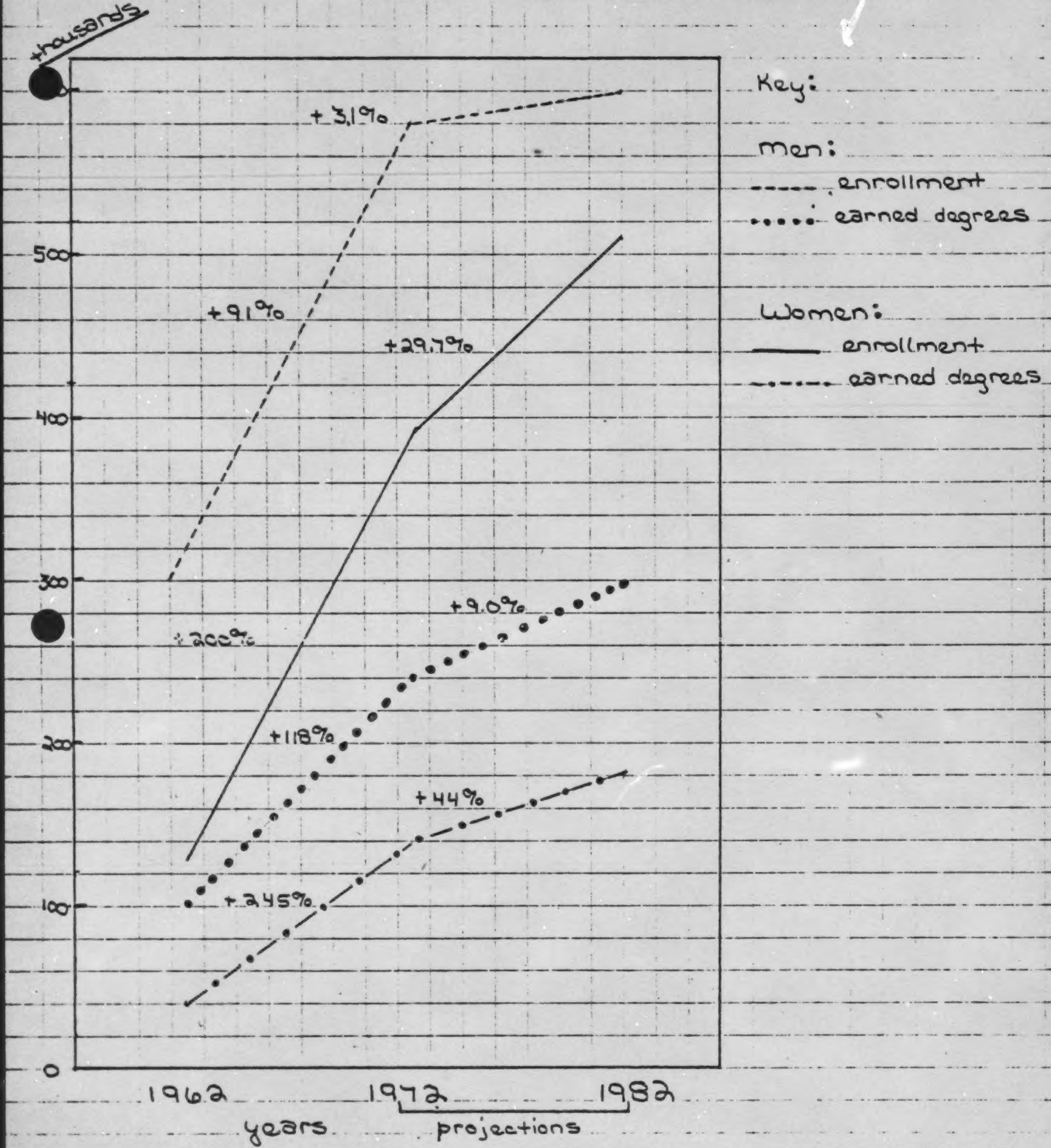
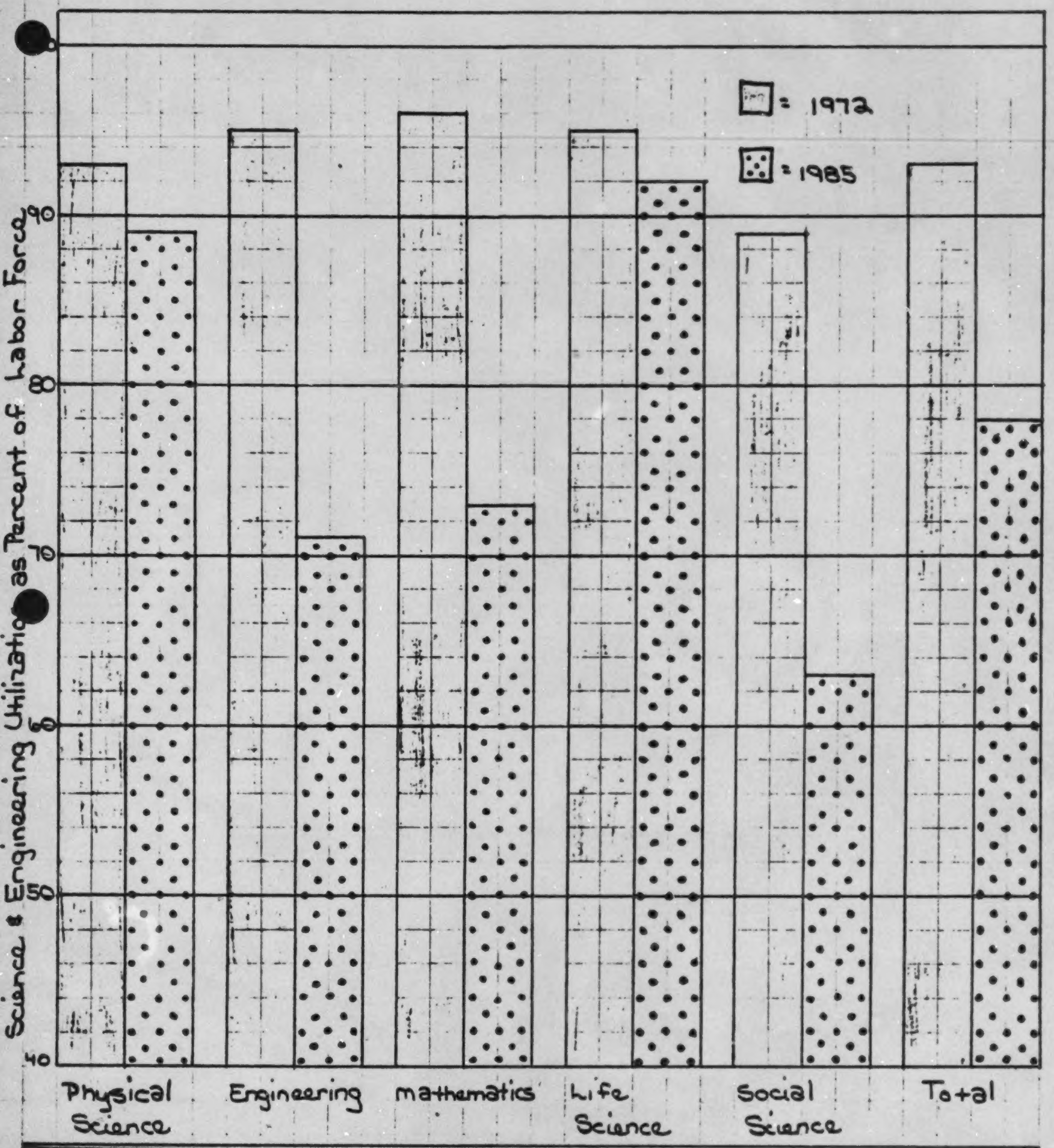
Source: National Science Foundation, Division of Science Resource Studies. Projections of Degrees in Science and Engineering Fields to 1985. Washington, D.C.: National Science Foundation, NSF 76-301. In preparation. Cited by permission.

Figure: I. Comparison of Advanced Degree Enrollment/Earned Degrees for Men and Women - 1962-1982



Source: Martin M. Frankel & J. Fred Beamer. Projections of Educational Statistics to 1982-83, 1973 Edition. National Center for Educational Statistics, Office of Education.

Figure 2. Utilization of Science and Engineering Doctorate Labor Force in Science and Engineering Jobs, by Field: 1972 and 1985



Source: National Science Foundation, Division of Science Resource Studies, Projections of Science and Engineering Doctorate Supply and Utilization, 1980 and 1985. Washington, D.C.: National Science Foundation, NSF 75-301, 1975.

SECTION 2

A Look At The Possible Future
Of Women In Science

To date, this report has examined in some detail the status of women in science, both historically and in the present. The question which arises at this point, based on the data heretofore presented, is simple: What can we say regarding the future of women in science? What expectations should we have, and what projections can we make? It is clear that any attempt to make informed projections regarding the future participation of women in science must at this point in time take into account at least two major factors, always being careful to bear in mind, of course, that projections can, at best, be made with a limited degree of certainty. These factors are first, the conservative cultural valence of the past centuries which placed women in a limited societal role at best; and second, the profound impact of the second feminist movement of the 1960's and 1970's, not only on women but on society as a whole. The future of women in science is inextricably tied to both historical trends, and will take its direction, finally, from that which proves most enduring in each. There is in addition a possible third factor, not as far-reaching, perhaps, but nonetheless critical to a cogent analysis and understanding of the often unexpected repercussions of the acknolwedged inroads made by the womans' movement and its legislative artificats on the American scene, and on the scientific community in particular. This factor is the so-called backlash which has resulted, at least in part, from the relatively recent efforts of the few women to ameliorate past injustices at a pace, or in a manner, which has proven unacceptable to many. The impact of this "backlash" on the sensibilities of a young woman considering a career in science will be considered throughout this section.

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Juxtaposed against the backdrop of broad historical trends such as we have outlined above, one also finds, inevitably, the smaller, subtler shiftings of individual lines and sensibilities. It is within this context that the weight of "psychological" and "sociological" factors is brought to bear and, further, that the impact of the individual experience on the collective process of social change is most fully felt. Thus, it is that a genuine understanding of the woman scientist cannot be reached without an examination of, and an empathic appreciation for, the unique psychological and sociological context within which women in science function. That they do function, and function well, within an extraordinarily demanding and often highly ambiguous professional role/structure, is by now a matter of record. How they cope, or fail to cope, with the attendant stresses and role conflicts has not, until recently, been nearly so well documented. This lack of documentation reflects not so much the rarity of the "coping phenomenon" but, on the contrary, is probably a testament to its ubiquitousness among professional women. By this, we mean simply that it is often most difficult to perceive that which has become a cultural commonplace, a "fact" of life. Women in so-called male professional have either "coped" or have dropped into statistical oblivion. Either way, a rigorous analysis of who in fact makes it, and how, and why, has until comparatively recent times been conspicuously lacking in academic literature. And the psychological subtleties underlying the statistics which are now emerging have just begun to be looked at.

To examine the net impact of psychological and sociological factors on the future participation of women in science is beyond the scope of this report. There is a burgeoning literature which has begun the monumental task of documenting the lost history of women in science, and which need not be repeated here. What we shall attempt, therefore, is simply a brief examination of only those psychological and sociological factors which we see as particularly salient to the personal and professional development of the future woman scientist. It is worth mentioning that here, as with any timely and controversial issue, the dust of debate both scholarly and otherwise has hardly settled around these topics. Thus, our interpretation of the available data should by no means be viewed as a final word on the subject. It is perhaps best taken instead as a "state of the art" commentary which reflects in nearly equal parts both the data itself and our admittedly subjective interpretation of it.

A final word is perhaps in order here regarding the rationale which underlies the application of a psychological/sociological analysis to the problems facing women in science. Psychologist Judith Bardwick has noted, as have we, that "... easy solutions, such as increasing stipends, child care facilities, changing tax laws, and retraining older women, are not likely to make much difference [to the participation of women in science]... if a woman is to be a scientist and not a (passive) lab assistant, she must be high in intellectual ability, fiercely persistent in work goals, extremely independent, and basically asocial."[1] Our analysis, therefore, will focus on those sociocultural factors currently impacting on the development of these critical traits in the woman scientist or scientist-to-be, leaving the proposal and disposal of "easier" solutions to others.

Women have traditionally remained relatively cool to choosing careers in science, clustering instead within the more familiar bounds of the arts and humanities. However, the advent of the Women's Liberation movement, as well as the

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[1] Bardwick, Judith, Ed., Readings on the Psychology of Women, New York: 1972. Introduction to Part II, "Socialization, Cultural Values and the Development of Motives," p. 49052, especially p. 50.

the stepped-up recruitment of women graduate students by all academic disciplines as a result of Affirmative Action mandates, might reasonably lead one to expect that today's young women are entering, or plan to enter, scientific training in numbers significantly greater than did their predecessors. The available data, however, do not support this assumption. It appears that the overall picture for women entering scientific careers has not changed much over the past decade. For example, in 1967, about 9% of American freshmen women said they intended to major in engineering, life science, physical science, or mathematics.[2] In 1973, the figure stood at only 10%,[3] despite a proliferation of special recruitment of women in science, it is clear that thus far its effect has been less than dramatic - in fact, quite a bit less. There appear to be a number of underlying psychological and sociological issues which remain unresolved for many, if not most women; issues whose ramifications we will examine briefly.

A review of the literature indicates that among the many psychosocial difficulties which have been cited as argument against women's full participation in scientific life, one theme occurs repeatedly: the perceived difficulty by young women of successfully combining the demands of a scientific career with those of family life. That this conflict has not been significantly ameliorated, despite the impact of the Women's Movement, of increased opportunity for part-time employment, or of innovative recruiting and public relations efforts aimed at changing the image of the women scientist, is the hypothesis which we are advancing. In an analysis of the 1962 Post-censal Survey conducted by the National Opinion Research Center, in which female college graduates were asked why they thought few American women enter medicine, engineering, or science, 80% of the respondents replied that they felt a medical career was "too demanding for a woman to combine with family responsibilities," and 54% felt the same way about a career as a research scientist.[5] (It is interesting to note that in these particular fields, the "unfeminine" nature of the profession was not considered a major obstacle, nor were women perceived as possessing inadequate skills to handle the job. This is in contrast to engineering, where the chief barrier cited was "Women are afraid they will be considered unfeminine if they enter this field."[6]) And looking at more recent data, we see this perceived problem of integrating "dual identities" persisting. For example, in a 1971 dissertation which analyzed data collected in 1968-69, entering women at the University of Michigan were asked what type of marital, parental, and career status they wanted "fifteen years from now."[7] By 1973, 76% of the respondents wanted to be married and 54.8% wanted a career as well.[8] When reinterviewed at the end of their freshman year, 85.7%

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[2] Pendleton, Deedee, "Women in Science: Reshaping the Stereotypes," Science News, March 15, 1975, p. 171-72, passim.

[3] Pendleton, "Women in Science," p. 171-72.

[4] Rossi, Alice, "Barriers to the Career Choice of Engineering, Medicine or Science Among American Women," Readings on the Psychology of Women, New York, 1972, (1st published 1965), p. 72-82; Pendleton, "Women in Science," p. 171-72; Einberg, Dorothy, "College: When the Future Becomes the Present," Women and Success, New York, 1974, p. 129-137.

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[5] Rossi, "Barriers to the Career Choice," p. 72-82.

[6] Rossi, "Barriers to the Career Choice," p. 72-82.

[7] Bardwick, Readings on the Psychology of Women, p. 49.

[8] Bardwick, Readings on the Psychology of Women, p. 49.

wanted to be married and 62.9% wanted a career too.[9] These data suggest that, despite certain feminist assertions to the contrary, for many if not most, young women marriage is still an extremely important factor in life planning. And thus the problem of effectively participating in both traditional as well as professionally achieving roles remains for these young women a central issue. With aspirations raised along with consciousness by the Womens Movement, today's female college student aspires, as indeed she should, to a considerably larger piece of the pie than did her mother. Getting it, however, is still not quite so simple as the media often would have her believe. Statistically, at least, the odds against successful combination of both roles are still great. For example, compared with over 95% of male Ph.D.'s who are married, only 50% of women Ph.D.'s are, while in the general population of a similar age group, 86% of the women are married.[10] It should be noted that this study was made in 1967 and whether the trend is the same at present is not certain. Implicit in these figures is a reality which at some point in a young woman's training for a career in science must be faced. The reality, obviously, is that many professional women remain unmarried — some certainly by choice, and happily, but many others for whom the decision not to marry will certainly bring acute personal conflict and stress. As the demands of professional training begin to make themselves felt over the wanted to be married and 62.9% wanted a career too.[9] These data suggest that, despite certain feminist assertions to the contrary, for many if not most, young women marriage is still an extremely important factor in life planning. And thus the problem of effectively participating in both traditional as well as professionally achieving roles remains for these young women a central issue. With aspirations raised along with consciousness by the Womens Movement, today's female college student aspires, as indeed she should, to a considerably larger piece of the pie than did her mother. Getting it, however, is still not quite so simple as the media often would have her believe. Statistically, at least, the odds against successful combination of both roles are still great. For example, compared with over 95% of male Ph.D.'s who are married, only 50% of women Ph.D.'s are, while in the general population of a similar age group, 86% of the women are married.[10] It should be noted that this study was made in 1967 and whether the trend is the same at present is not certain. Implicit in these figures is a reality which at some point in a young woman's training for a career in science must be faced. The reality, obviously, is that many professional women remain unmarried -- some certainly by choice, and happily, but many others for whom the decision not to marry will certainly bring acute personal conflict and stress. As the demands of professional training begin to make themselves felt over the undergraduate years, combined with societal pressure on young women — and their own desire -- to establish successful relationships with males, the attrition rate, particularly in the sciences, rises sharply.[11] Thus, despite the impact which the Women's Movement has undoubtedly had, and which it is probably too early to assess, it can still be said of contemporary young women that "although more of them have come to college with career plans, the plans take on the same tentative, vague outlines as did those of their predecessors, and the future fades under the burden of immediate pressures. That even the more definite plans of the seventies begin to pale makes more obvious the extent of the immediate pressures that have been underestimated or at least not seen sufficiently clearly. The young woman must resolve both her sexual identity and her career identity at the same time. It is not surprising to learn from recent studies of women undergraduates that, unlike their male peers, they become less happy over the four years, and as seniors are less career-oriented than they were as freshmen."[12]

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[9] Bardwick, *Readings on the Psychology of Women*, p. 49.

[10] Simon, Rita J., Clark, S.M., and Galway, K., "The Woman Ph.D.: A Recent Profile," Vol. 15, No. 2, Fall 1967, p. 221-237, *passim*.

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[9] Bardwick, Readings on the Psychology of Women, p. 49.

[10] Simon, Rita J., Clark, S.M., and Galway, K., "The Woman Ph.D.: A Recent Profile," Readings on the Psychology of Women, Social Problems, Vol. 15, No. 2, Fall 1967, p. 221-237, passim.

One might conclude from the above discussion that educational intervention aimed at increasing both the number of women aspiring to scientific careers, as well as the number persisting in their aspirations throughout the often lengthy training period, must be aimed at young women before they reach the freshman year of college, by the end of which the greatest number of would-be scientists drop out.[13] We have looked at several of the most interesting new programs which attempt this early intervention and the available data, much of which admittedly is preliminary, indicates mixed results. At Purdue, for example, where in an experiment conducted in 1974, academic advisors spent approximately four times as many hours with a randomly selected group of freshman women science majors than had been the practice in the past, attrition rates did drop by almost 50%.[14] Although these results are encouraging, one is also forced to observe that it is probably unrealistic in terms of cost-benefit analysis to expect to justify the implementation of such an intensive program on a broader basis. One wonders also whether a program of this sort, which involves intensive short-term remedial support services, will meet with much the same fate as did, for example, many Headstart programs, where lack of sufficient follow-up due to the prohibitive costs of highly individualized instruction quickly cancelled out many of the initially positive effects of the program. Another "early intervention" program has developed a series of science-oriented workshops for high school women.[15] This program makes use of female scientists as personal role models, provides for fieldwork whereby students interview women scientists at work, reports on occupational alternatives to traditional careers for women, and encourages career role-playing by students. Preliminary results indicate the following: those girls who were already interested in scientific careers appear to have gained a broader view of alternatives available to them. However, those who were not interested initially did not significantly increase their interest in science as a result of the course.[16] In speculating on possible reasons for these results one potentially unpopular observation should be made. A primary focus in this program, as in many others dealing with change in role-expectation in young women, was to provide increased accessibility of student to strong female role models.

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[11] Zinberg, "College," p. 129-137.

[12] Zinberg, "College," p. 132.

[13] Zinberg, "College," p. 132.

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[14] Pendleton, D., "Women in Science," p. 171-172.

[15] Newton, Virginia, Ebbs, S., et al, "Science-Oriented Career Development Workshops for High School Girls - A Progress Report," NSF Project GY-11329, 1974.

Although the importance of such modeling cannot be denied, one might ask why there has not been similar emphasis placed on the importance of providing successful male role models for young women as well. In light of extensive research indicating the early presence of an achieving, ambitious, yet supportive male figure as perhaps the most salient factor influencing the development of successful women, and also in view of the strong need of adolescent women in particular to successfully integrate interpersonal relationships with males with career strivings,[17] one cannot help but wonder why this aspect of educational development has been overlooked. Perhaps, there is a pancity of appropriate males, but what is more likely, one suspects, is a current tendency in many circles to devalue, or at least leave unexplored, the potentially positive effect of male influence on young women for fear of resurrecting the very system of male dominance which has proven so oppresive to women in the past. A return to patriarchy is not being advocated here. But in view of observations such as the following, certain conclusions are inescapable: "...those young women who maintain eighth grade science and technology career decisions will have high male sex-role identity and high career commitment."[18] "Creative, achieving women are often ambivalent toward their mothers and identify with fathers who use intellectual activity to express themselves and give purpose to their lives, and who have strong symbolic interests and a need for autonomy."[19] "The single most important factor in arousing fear of success is the girl's perception of the attitude of her male peers. The single best predictor of the behavior of women is the attitude of the man with whom they are involved." [20] We are thus suggesting that it might be valuable to begin to reconsider the potentially positive effects which an apprentice-like affiliation with a successful male figure might have for young women, as well as providing an opportunity to begin the difficult integration of personal and professional roles all available data has shown to be central to women's reluctance to enter science.

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[16] Newton, "Career Development Workshops."

[17] Bardwick, Readings on the Psychology of Women, p. 49-52, passim; Kotcher, Elaine, "Identifying Young Women Who Maintain Early Decisions to Enter Careers in Science and Technology - A Progress Report," NSF Grant GY-11313, 1975, passim; Lozoff, Marjorie M., "Fathers and Autonomy in Women," Women and Success, New York, 1974, p. 103-109, passim.

Let us look now at another of the so-called "easy solutions" cited at the beginning of this section, that of part-time employment for women. Part-time employment has been proposed as a workable solution to the role conflict facing women today. It provides greater flexibility in terms of schedule and professional demands, and enables women to "keep a foot in the door" while devoting a significant portion of their time to domestic concerns. What it does not provide is an avenue for increasing the legitimacy of women's claim to the rewards of academic and professional achievement; first, by perpetuating the still-popular image of women as peripatetic dabblers in the real world, and second, by encouraging women to withdraw from the labor market during precisely those years which generate the greatest creative achievement in both men and women.[21] For the future, women choosing to "go part-time" will do well to keep in mind Alice Rossi's observation concerning the uncritical acceptance of this seemingly innocuous solution to a complex set of problems:

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[18] Kotcher, "Women Who Maintain Early Decisions," passim.

[19] Bardwick, Readings on the Psychology of Women, p. 49-52, passim.

[20] Bardwick, Readings on the Psychology of Women, p. 49-52, passim.

> "Part-time employment is this generation's false panacea for avoiding a more basic change in the relations between men and women, a means whereby, with practically no change in the man's role and minimal change in the woman's, she can continue the same wife and mother she has been in the past, with a minor appendage to these roles as an intermittent part-time professional or clerical worker...women's most creative years in science do not differ greatly from the creative years of men. The most creative work women and men have done in science was completed during the very years contemporary women are urged to remain at home rearing their families...I think this is a point well worth bearing in mind in a period when women are enticed to believe that withdrawal from the labor force in their twenties, followed by part-time employment in their forties is their modern panacea to the conflict in women's role."[22]

Although part-time employment has provided an important service for many women, an uncritical and often inflated evaluation of its merits is in fact a disservice, perpetuating as it does the myth of easy solutions to complex dilemmas.

Having touched upon several themes which appear to characterize the participation of women in science, let us look now at those factors which characterize the woman who drops out of science, i.e., the problem of attrition. There is a paucity of data available relating to attrition of women science. What data there is is fragmentary and much of it is speculative. One point which is clear, however, is that the participation of women in science is characterized by high attrition rates at every stage of the career, ranging from switching majors during the freshman year of college, to dropping-out at the non-terminal masters degree level, to underutilization of training after the Ph.D. has been earned. Of the 30% of both men and women science majors who drop out of science during the undergraduate years, far fewer women than men quit because of academic failure.[23] This has led educators and psychologists alike to look elsewhere for possible causes. Attrition has been attributed variously to fear of success in women, to anticipated role-conflict between professional and wife/mother roles, to the lack of adequate female model roles, to a general ambiance of lowered expectation for women which results in lowered performance. And, more recently, depressed economic conditions and a poor employment picture have been cited as additional factors. In this section, we shall discuss several of these factors, with particular attention being given to a possible alternative interpretation of "fear of success" data, and to the possible importance of appropriate male role models facilitating integration between women's dual identities. We will also touch briefly upon the implications of the following findings, drawn from recent limited data, which indicate that: 1) financial support greatly reduces the attrition rate for women in science, particularly in the physical science and social sciences; 2) the presence of children is a positive factor in both male and female attrition, though more markedly so for females; 3) the sponsor-apprenticeship relationship, or lack of it, is a significant factor; 4) drop out at the masters degree level accounts for significantly greater female attrition than it does for males.[24]

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[21] Rossi, "Barriers to the Career Choice, " p. 72-82, passim.

[22] Rossi, "Barriers to the Career Choice," p. 72 and 76.

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[23] Pendleton, "Women in Science," p. 171-172.

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One of the few available studies which examines the factors influencing women in science career choice and stability, and attempts to identify critical points at which attrition occurs, is discussed in a 1975 unpublished progress report by Skypek and Lee.[25] Although the data is preliminary, it indicates several interesting points. In a sample of high school seniors interviewed at the end of their senior year, and reinterviewed five years later, preliminary findings indicate that only .36% of the women aspiring to scientific careers had persisted in actually following their early aspirations, while some 3.2% of their male peers did so.[26] Skypek and Lee found also that 70.2% of the males made their first decision on whether to pursue a career in science while in high school, while fully 70.3% of the women did not make this important early decision until leaving high school.[27] This delay in concretizing career plans and the attendant lack of appropriate academic preparation and beginning socialization to "career oriented" role behavior is apparently critical to the young women entering the increasingly competitive realm of higher education, for college, though looked upon as a preparation for future life, is in fact very much a career in itself.

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[24] Patterson, Michelle and Sells, Lucy, "Women Dropouts from Higher Education," Academic Women on the Move, New York, 1973, p. 79-91, passim; Bernard, Jessie, Academic Women, New York, 1964, p. 58.

[25] Skypek, Dora H., "A Study of Factors Which Influence Women and Blacks in Science Career Choices - A Progress Report," NSF Grant GY-11321, 1975.

[26] Skypek, "Factors Which Influence Women."

[27] Skypek, "Factors Which Influence Women."

And it is a career for which women, by and large, are still unprepared.

In Lucy Sells' analysis of a 1966 study of Woodrow Wilson fellows entering graduate school from 1958-1963, she also found sex differences of large magnitude in attrition rates at this more advanced career stage.[28] For example, attrition rates for women social scientists were 18 percentage points higher than for males, and in physical sciences, there was a difference of 28 percentage points.[29] However, when Sells looked at those students receiving second year financial support, sex differences in attrition were reduced overall from 20 percentage points to 9.[30] Attrition rates for women were reduced by 26 percentage points, and for men by 14 percentage points.[31] In the physical sciences, there was a dramatic drop of 40 percentage points for women fellows receiving support; in social sciences there was a 17 point drop.[32] Clearly, financial support, though important for both men and women, is a more crucial factor in determining whether women will stay in scientific training. Sells notes also that when the presence of children was taken into account, attrition rates for women in the physical sciences, for example, rose by 31 percentage points.[33] "Unfortunately," states Sells, "it is not possible to infer...whether women drop out of graduate school because they have babies, or whether they have babies as a face-saving alternative to trying to succeed in a discriminatory graduate system."[34]

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[28] Patterson and Sells, "Women Dropouts," p. 84-89.

[29] Patterson and Sells, "Women Dropouts," p. 84-89.

[30] Patterson and Sells, "Women Dropouts," p. 84-89.

[31] Patterson and Sells, "Women Dropouts," p. 84-89.

[32] Patterson and Sells, "Women Dropouts," p. 84-89.

[33] Patterson and Sells, "Women Dropouts," p. 84-89.

Further data on women in the physical sciences is available from a 1972 review submitted to the Council of the American Physical Society by the Committee on Women in Physics.[35] This data shows a tendency for women doctoral students to drop out at the masters degree level in far greater numbers than do men. For graduate physical sciences students entering the University of Chicago in 1962-64, the attrition rate for male doctoral students was 48%; for women it was 76%.[36] For those students aspiring to either the masters or the Ph.D., the attrition rate for males was 35%, while women dropped out at a lower rate of 28%.[37] Thus, dropout at the masters degree level accounted for almost four times the attrition among women graduate students than for men (48% for women, 13% for men).[38] This trend, if indeed it is one, of women terminating their professional training with a non-terminal masters degree, a degree which is "respectable" but which does not provide the union card of professional status which the Ph.D. does, may be observed in recent computer science projections as well. In this relatively new field, women appear to be opting for masters degrees while men, on the other hand, are earning far fewer masters degrees and far more Ph.D.'s and B.A.'s.[39] Perhaps the masters level of computer science may soon become still another haven for highly trained yet relatively powerless female technicians.

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[34] Patterson and Sells, "Women Dropouts," p. 84-89.

[35] "Women in Physics, the Report of the Committee on Women in Physics," Bulletin of the American Physical Society, June 1972, passim.

[36] "Women in Physics," passim.

[37] "Women in Physics," passim.

[38] "Women in Physics," passim.

Sociologist Cynthia Epstein has outlined a number of complex cultural mechanisms which foster, and in fact exacerbate, the difficulties which women have in maintaining an initial decision to enter a professional career.[40] Her observations are particularly germane to the problems faced by women in science where, due to the rapid pace of scientific and technological advancement, there is a "knowledge explosion": As a result, scientists are dependent upon their contacts within their respective fields as much, if not more, as they are upon the literature. As Jessie Bernard noted in the early sixties, women scientists, especially academic women scientists, are particularly isolated in this respect. They are outside the network.[41]

Access to these persons is essential to professional advancement and development of competence; Epstein too maintains that women are denied this informal access through a variety of mechanisms. Her analysis provides a cogent and thought-provoking view of some of the real factors underlying female attrition, and is worth reviewing in some detail.

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[39] Kistiakowsky, Vera, *Women in Engineering, Medicine and Science*, Washington, D.C.: National Academy of Sciences/National Research Council, Revised Edition September 1973, Table II, "Number and Percentage of Degrees Awarded in Architecture, Computer Science, and Engineering in the Periods 1962-71 and 1971-81 (Projected) by Degree, Level and Sex," (National Center for Educational Statistics, D.H.E.W.,) p. 5.

[40] Epstein, Cynthia Fuchs, "Encountering the Male Establishment: Sex-Status Limits on Women's Careers in the Professions," American Journal of Sociology, 75 (1970) p. 965-82, *passim*.

[41] Bernard, Jessie, *Academic Women*, New York, 1964, p. 158-9.

Several of Epstein's formulations are grounded in the work of Harvard psychologist Robert Rosenthal, who has established conclusively that lowered expectations by professors and other authority figures result in lowered performance by students.[42] Even in cases where identical verbal test instructions are read to students, those students about whom the professor has been led to have lowered expectations, i.e., those deemed less bright, less competent, less likely to succeed, deliver poorer performances on objective tests than do those seen as "winners."[43] Since women are not often seen as "winners," potential members of the elite, Epstein maintains that less is therefore expected of them both academically and personally, particularly by those in positions of authority and that less is therefore "delivered" by the women themselves. The fact that women are not forced, or expected, to do denies them the opportunity to deal with their fears of achieving and to overcome them. According to Epstein, women are instead allowed, even encouraged, to take the easy way out of various professional conflict situations, and are thus denied the opportunity of being subjected to the discipline of their profession which is crucial to refinement and improvement of both their performance and their attitudes.

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[42] Harris, Ann Sutherland, "The Second Sex in Academe," A.A.U.P. Bulletin, Fall, 1970.

[43] Harris, "Second Sex."

[44] Epstein, "Encountering the Male Establishment."

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Epstein further maintains that women professionals are rewarded and punished as women, not as professional persons: "Often they are rewarded for merely adequate performance (any performance by a woman is considered unique,) or their deficiencies are attributed to women as a class of persons, rather than to the individual...women are rewarded for irrelevant performances or ignored entirely.[45] Also, "the secondary rewards women typically receive also pull them off course. They do not compete, nor do they ever put their capacities and talents on the line."[46] In being subjected to a different set of rules than are males, some so subtle that the individual woman may not be aware of them until it is too late, women are denied the opportunity to sharpen their competence, and thus become their own worst enemies. Women are socialized, instead, to be other-directed, and are thus denied the opportunity for autonomy and independence which have been cited as integral to the personal characteristics of the successful scientist.[47] They are asked to demonstrate competence in a wide range of roles, yet are expected to do well in only the more traditional ones. This series of double-messages does not escape the young female student, and is undoubtedly a major factor in the high rates of attrition which have been observed among women in science.

Epstein's second major point is that women are generally denied access to the all-important academic and professional protege system. As one progresses up the career ladder, who one knows, i.e., sponsorship by respected members of one's profession, rapidly becomes as important as what one knows. Since there are no objective tests for competence at high levels, competence is created by "exposing the new professional to the tasks."[48] This includes access to and acceptance by those in authority, as well as consistent feedback and judgment of performance from those older professionals judged expert. Lack of access to such informal communications and sponsorship has been cited in various studies as both critical to, and missing from, the "grooming" of the female graduate student and young professional.[49] For example, Lucy Sells finds in a recent study of doctoral attrition that "...the sponsor-apprenticeship relationship is crucial in accounting for both sex and discipline difference in doctoral attrition."[50] This conclusion was based on data which indicated that in the scientific fields sampled over half of the male faculty members had received "sponsorship" while graduate students searching for a first job, while less than half of the women faculty had been sponsored (with the exception of women in social sciences.)[51]

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[45] Epstein, "Encountering the Male Establishment."

[46] Epstein, "Encountering the Male Establishment."

[47] Rossi, "Barriers to the Career Choice," p. 72-82, passim.

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[48] Epstein, "Encountering the Male Establishment."

[49] White, Martha S., "Psychological and Social Barriers to Women in Science," Science, Volume 170, October 23, 1970, p. 413-416; Epstein, Woman's Place, p. 19; Patterson and Sells, "Women Dropouts," p. 84-89.

[50] Patterson and Sells, "Women Dropouts," p. 84-89.

[51] Patterson and Sells, "Women Dropouts," p. 84-89.

Epstein therefore characterizes women as "unwanted professionals" who, by definition because they are women, are not seen as potential members of the elite and are therefore given confusing and exclusionary messages by those in authority.

> "Those who teach the young professional and those who lead the profession usually agree that the "appropriate" candidates are competent and will later become more competent in important ways beyond their talents and formal training. They agree, too, that the "inappropriate" candidates cannot become competent. It is believed that those with the "wrong" statuses cannot be part of the subtle, informal collegial system, will be unable to catch the messages, will be ill-prepared in the necessary etiquette of professional behavior and rules of reciprocity, and will be incapable of proper behavior toward a hierarchy that may not be clearly labeled -- for them. Cleverness is not sufficient, nor is a professional degree. Because failure is presumed, few act as sponsor for the unwanted professional."[52]

Not knowing the rules, they in turn perform poorly, thus justifying the negative assumptions made about them initially. This self-fulfilling prophecy is exacerbated by women's lack of access to the informal communications network, the "grapevine," through which most important information is relayed and critical career-influencing decisions made. In other words, women are not groomed for leadership roles in the myriad of samll ways in which society -- through its social clubs, its academic and financial institutions -- endeavors to influence the character development of those youth whom it perceives, and thereby selects, as marked for future responsibility and privilege. Max Weber has called this refining process "charismatic education."[53] It is an essential dimension to the creation of competence in the neophyte, and one from which women are as a class excluded.

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[52] Epstein, "Encountering the Male Establishment."

[53] Epstein, "Encountering the Male Establishment."

Along with sociological data, many psychological theories have been advanced to explain the failure of apparently competent women to achieve equally with men in professional life. One of the most timely and controversial of these is the so-called "fear of success" syndrome. In her classic 1964 study, Radcliffe College president and psychologist Matina Horner discovered that when college sophmores were given a lead story-line which read "After the first-term finals, Anne ("John" for male respondents) finds herself at the top of her medical school class", significantly different types of stories were obtained from male and female students.[54] 65% of the women gave stories containing projected negative or bizarre consequences for Anne, while only 10% of the males responded negatively to the "John" lead.[55] Women's stories stressed that Anne was unhappy, aggressive, unmarried, and manipulatively ambitious. Males, on the other hand, stressed positive material and psychological benefits for John, increasing striving, confidence in the future, and a belief that John's success would be instrumental in fulfilling other important goals. In her analysis of the data, Horner maintained that women's negative projections were indicative of a "fear of success". Indications that this attitude was increasing were seen in a 1970 replication of the original study. Compared with 1965, negative attitudes toward "Anne" expressed by female respondents had increased from 65% to 88.2% while male negative attitudes had increased from 10% to almost 50%.[56] Horner attributed this increase variously to the development of a cultural backlash reacting against the impact of the Womens Movement, an increased societal tendency to view achievement and/or competition negatively, and a persisting tendency of women to view achievement and femininity as incompatible.

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[54] Horner, M.S. and Walsh, M.R., "Psychological Barriers to Success in Women," Women in Success, The Anatomy of Achievement, New York, 1974, p. 140.

[55] Horner, Psychological Barriers," 1974, p. 140.

[56] Horner, "Psychological Barriers," p. 140.

The increased male negativity to a conventional "success story" does in fact suggest that a cultural reassessment of the importance of this type of achievement is occurring, accompanied by a strong rejection of the conflicts which success presents for the individual. (It is interesting to note that while both men and women may be rejecting traditional achievement more for members of their own sex, at least one recent study indicates that men, however, may be becoming more supportive than women of achievement by women.[57] Only 62.5% of a sample of male Dartmouth College students gave avoidance stories in response to the "Anne" stimulus, while the same lead drew avoidance stories from 89% of a sample of Wellesley women undergraduates.[58]) And although there have been some problems in replicating the Horner studies,[59] at least one source considers this to be a function "more of wide methodological differences from study to study than of basic instability of the motive."[60] Thus

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[57] Alper, Thelma G., "Achievement Motivation in Women: A Now-You-See-It-Now-You Don't Phenomenon," American Psychologist, March 1974, p. 194-203.

[58] Alper, "Achievement Motivation in Women," p. 194-203.

[59] Levine, Adeline and Gumrine, Janice, "Women and the Fear of Success: A Problem in Replication," American Journal of Sociology, Volume 80, No. 4 January 1975, p. 968-874.

[60] Alper, "Achievement Motivation in Women," p. 194-203.

Horner's finding that a significant number of white, middle class women react with negative attitudes to a hypothetical situation depicting a professionally successful woman, and that negative attitudes by males toward male success are increasing as well, is a finding which appears to have a basis in reality. Attributing this complexity of attitudinal changes mainly to a "fear of success" may, however, prevent us from considering other possible interpretations of the data. We are suggesting the possibility that negative attitudes expressed by women toward conventional success stories may be indicative not so much of a neurotic "fear" of success as they may reflect a realistic awareness of the increasingly high personal price which one pays for success in the United States today. This is a price which most women still do not wish to pay, and their negative responses to a professional success story may simply reflect this legitimate decision. For the "belief that unusual excellence in women is associated with a loss of femininity and social rejection" cited by Horner is after all not merely a belief.[61] It is a cultural truism upheld by extensive psychosocial data which finds aspiring women professionals less social, dating less, marrying later, marrying less, than does the popualtion at large.[62] Thus, whether Horner's negative respondents are in fact afraid of success, or are merely expressing their cognizance of the personal price which success still in fact demands of many women, is a question which should be considered more carefully than the recent rapid popularization of the "fear of success" theory would seem to indicate.

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[61] Horner, "Psychological Barriers," p. 140.

[62] Zinberg, "College," p. 132.

In summary, while the psychological and sociological causes of underparticipation and attrition among women in science are far from being clear, several themes do emerge which bear watching. First, women are not asked for as much; expectations are lower as is constructive criticism directed at both task performance and "professional" role-playing behaviors. Lowered expectations lead to poorer performance by women, who are consequently labeled "unwanted professionals" from whom less is then expected. This destructive spiral, coupled with lack of access to both the informal communications network within one's profession and to the protege system of professional sponsorship, insures that even women who make it to the top will, as Epstein notes, be found "at the bottom of the top."[63] Second, suffering the price to be paid for professional success is an experience common to many more women, one would guess, than is savoring the rewards which success may bring. It should not be surprising, therefore, to find that women respondents in academic studies stress in their fantasies the negative aspects of success rather than its rewards. This may in fact be no fantasy. Whether it is evidence of a "fear" of success, or is rather a shrewd appraisal, based on both personal and cultural experience, of how success is in fact likely to affect the real life of the average female student, is as yet unclear. What is suggested by the increasing negativity expressed by respondents of both sexes is that 1) a broad cultural reassessment of the value and meaning of success is underway, and 2) in the privacy

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[63] Epstein, "Encountering the Male Establishment."

APPENDIX

Types of Data Available by Field
from Women's Professional Groups
(Caucus and Committee Reports)

TABLE 1 - EMPLOYMENT DATA BY FIELD

	ANTHROPOLOGY	ASTRONOMY	CHEMISTRY	ECONOMICS	ENGINEERING	GEOSCIENCE	MATHEMATICS	METEOROLOGY	MICROBIOLOGY	PHARMACY	PHYSICS	POLITICAL SCIENCE	PSYCHOLOGY	SOCIOLOGY		
I. ACADEMIC																
Distribution																
By calendar year						x			x	x			x			
By type of school	x	x	x	x												
By academic rank	x	x	x											x		
By tenure status		x		x			x	x	x		x	x	x	x		
By salary		x	x	x					x		x	x	x	x		
Work Activity						x			x			x	x	X		
Teaching									x							
Research							x									
Grad. student supervision							x									
Administrative (committees)																
Other							x		x			x				
Mobility																
Within an institution	x	x														
Between institutions									x							
Part-time Work		x		x			x				x		x			
II. GOVERNMENT AND NATIONAL LABS																
Distribution																
By calendar year		x				x	x	x	x		x		x	x		
By rank												x	x	x		
By salary				x				x	x							
Work Activity		x	x						x				x			
Research									x							
Administration			x					x								
Other			x					x	x							
Mobility																
Within an institution									x							
Between institutions																
III. PRIVATE NON-PROFIT INSTITUTIONS																
Distribution/Numbers																
By calendar year		x				x			x	x	x					
By rank																
By salary									x							
Work Activity		x	x						x							
Mobility			x					x	x							
Within an institution																
Between institutions									x							
Part-time Work																
IV. INDUSTRY																
Distribution																
By calendar year		x			x	x		x	x	x	x	x				
By rank																
By salary									x				x			
Work Activity		x	x		x	x		x	x					x		
Mobility			x		x				x							
Within a company																
Between companies									x							
Part-time Work		x														
V. SELF-EMPLOYED						x		x								

TABLE 2 - DATA ON WOMEN STUDENTS

	ANTHROPOLOGY	ASTRONOMY	CHEMISTRY	ECONOMICS	ENGINEERING	GEOSCIENCE	MATHEMATICS	METEOROLOGY	MICROBIOLOGY	PHARMACY	PHYSICS	POLITICAL SCIENCE	PSYCHOLOGY	SOCIOLOGY		
I. STUDENT ENROLLMENT					x					x						
By Calendar Year			x											x		
By Immediate Degree Sought		x	x	x										x		
By Type of School				x										x		
II. DEGREES GRANTED																
By Calendar Year		x					x		x		x	x				
By Type of Degree		x				x	x			x						
By Type of School																
By Subspecialty							x		x		x					
III. FINANCIAL SUPPORT									x		x		x	x		
By Immediate Degree Sought							x									
By Type of Support							x									
By Dollar Amount		x														
By Field																
IV. SCHOLARSHIP DATA								x								
V. ATTRITION RATES											x	x		x		
Overall																
By Calendar Year																
By Degree Sought																
By Marital and Family Status		x														
VI. PART-TIME STUDY																
Enrollment Data		x														
School Policies																
VII. EFFECT OF ROLE MODELS														x		

TABLE 3 - CHECKLIST OF DATA AND INFORMATION RELATED TO THE PROJECT

	ANTHROPOLOGY	ASTRONOMY	CHEMISTRY	ECONOMICS	ENGINEERING	GEOSCIENCE	MATHEMATICS	METEOROLOGY	MICROBIOLOGY	PHARMACY	PHYSICS	POLITICAL SCIENCE	PSYCHOLOGY	SOCIOLOGY
I. PARTICIPATION IN PROFESSIONAL ACTIVITIES														
Professional Societies		x									x	x	x	
Office holders		x									x	x		x
Board and committee members		x					x				x	x	x	
Professional Meetings									X		x	x		
Session chairs		x											x	
Invited papers		x												
Participants														
Journals														
Editors							x							
Paper referees		x					x					x		
Articles published							x				x	x		x
Contracts, Grants, and Awards		x									x	x		x
II. OVERALL DATA									X					
Total Number and Percentage of Women	x	x			x	x			X		x			
By calendar year														
By age		x												
By degree		x												
By subspecialty		x						x	X					
Unemployment/Underemployment														
By calendar year						x								
By degree			x											
By marital status														
By age			x											
Overall Salaries					x									
III. EFFORTS BY EDUCATIONAL INSTITUTIONS TO ELIMINATE DISCRIMINATORY PRACTICES														
Elimination of Nepotism Rules		x						x	X		x		x	x
Maternity/Paternity Policies											x			
Day Care Provisions													x	x
Recruitment Efforts														
Affirmative Action Efforts		x												
IV. OTHER RELATED INFORMATION														
Effect on Publication Performance of								x	X					
Marital status		x						x	X					
Family responsibilities														
Profession of spouse														
Attitude of spouse		x												
Effects of Career Interruption								x	X					
Effects of Attitude of Colleagues														
Degree of Career Satisfaction		x											x	
Perception of Discrimination		x						x	X					
Sex-linked Obstacles to Career Aspirations														
V. ROSTERS	x	x						x	X		x	x	x	

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